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FEATURES

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RAY T. BAYLESS, *Editor*

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A NOTE ON THE EXPANSION DUE TO NITRATION OF A SPECIAL ALLOY STEEL

BY RAYMOND H. HOBROCK

Abstract

There is an expansion occasioned by the nitration process alone that may not be eliminated by an annealing operation. The amount of this expansion is a function of the time of treatment and of the thickness of the case produced. Data has been gathered and correlated for one such alloy and is presented in such form as to make the calculation of the amont of expansion quite simple.

EXPANSION DUE TO NITRATION OF SPECIAL ALLOY STEEL

THERE is being introduced to industry a new group of alloy steels, which are intended for use in the production of surface hardened articles. The surface hardening is accomplished by treatment of the articles with active nitrogen at rather low temperatures (about 875 degrees Fahr.) which results in the formation of iron and other nitrides and so produces a case of great hardness. The nitration is generally accomplished by treatment of the special steels with ammonia gas at the prescribed temperature.

Since this kind of case may be established simply by nitration and without any subsequent quenching or tempering operations, one of the great advantages in the use of these alloys is that they permit the piece to be practically finished before the case is produced. Before the finishing operations have been made on the piece, however, it is necessary to relieve any stresses that might

The author, Raymond H. Hobrock, was associated with the Engineering Experiment Station, Purdue University, Lafayette, Indiana. **Manuscript received June 8, 1928.**

have been set up in the previous machining or fashioning operations. This is generally accomplished by annealing for about five hours at 1000 degrees Fahr.

It has been noticed, however, that the nitrided specimens

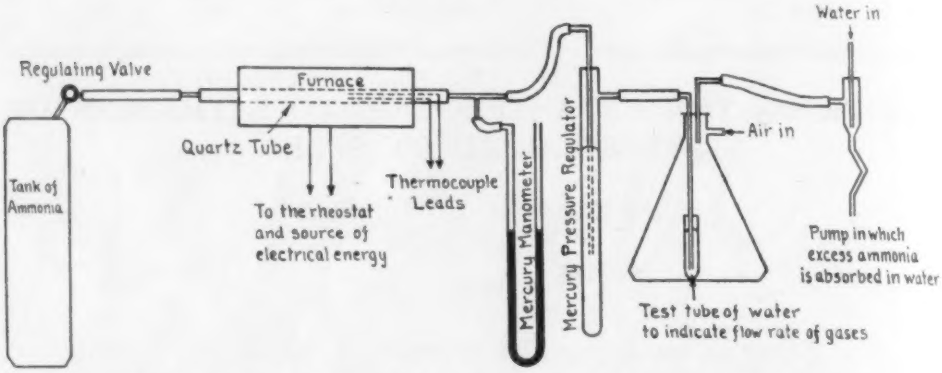

Fig. 1—Schematic Diagram of the Apparatus for Pressure Nitriding.

change in size during the process, the change being ascribed to the nitration process and not to any movement occasioned by internal stresses. This change in size is of a small magnitude but may

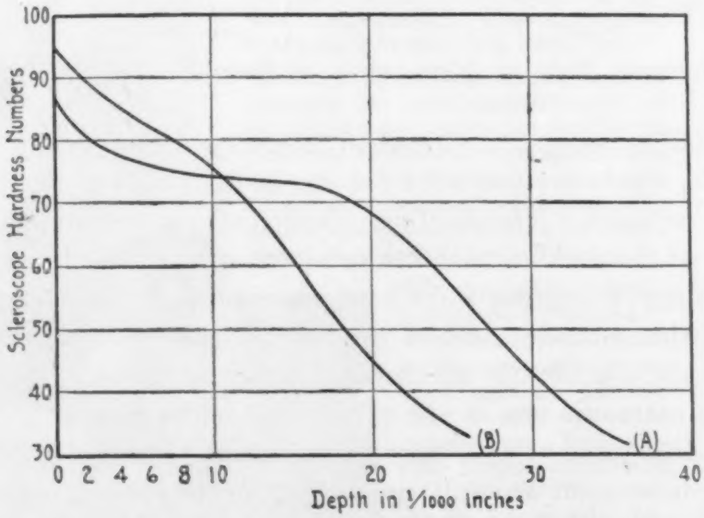

Fig. 2—Relation Between Hardness and Depth of Nitrided Specimens. (A) Treatment for 94.5 Hours at 600 Millimeters above Atmospheric Pressure. (B) Treatment for 100 Hours at Atmospheric Pressure.

be comparatively very large where the pieces nitrided are to be held within very small limits. In such cases, then, a small amount of material might have to be removed after the nitriding (usually by grinding) in order to finish within the required limits. The

amount of material so removed should be small; first, from the standpoint of economy, and second, because the removal of a small amount of this surface material results in a considerable decrease in hardness as is apparent from curve, Fig. 2, which shows the relation between hardness and depth of the case for a typical steel.

If the magnitude of this expansion upon nitriding is rather accurately known, then the designer of pieces to receive this treat-

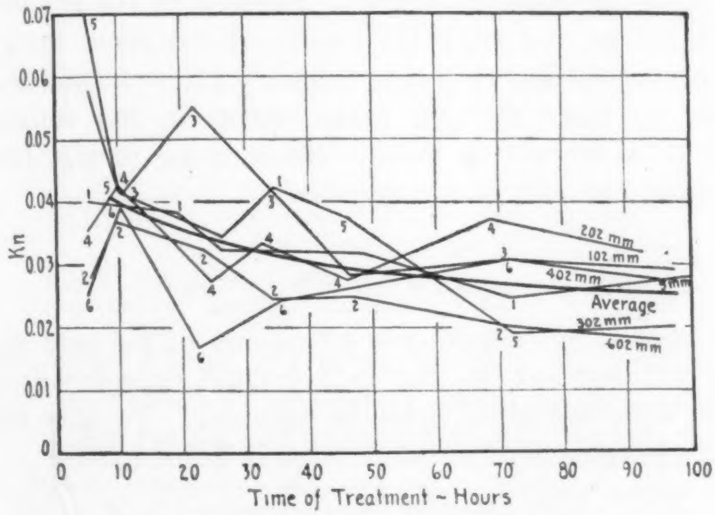

Fig. 3—Relation Between Expansion Coefficient and Time in Nitriding Specimens of Steel.

ment can make proper allowances for this increase in size and so avoid the removal of much material after the treatment.

During the course of an investigation of these alloy steels, made in the department of practical mechanics at Purdue University, observations were made on this change in size, the results of which are set forth in this paper.

Experimental

The specimens were cylinders 11/16 inch in diameter and 0.5 inch long, made from a steel of the following composition.

	Per Cent		Per Cent
Carbon	0.38—0.43	Aluminum	1.00—1.25
Silicon	0.20—0.30	Molybdenum	0.15—0.25
Manganese	0.40—0.60	Nickel	0.30—0.60
Chromium	1.60—1.80		

These specimens were treated in the apparatus shown in Fig. 1, for various periods of time and under various pressures of the gas.

The hardness at various depths was determined by removing a small, measured, amount of material from the surface and determining the hardness. This was continued until the hardness became the same as the hardness before the material had been treated. The hardness of the untreated material in this case was 31 on the scleroscope scale but the depth of the case was taken to be that depth at which the hardness became 32 since this was more clearly defined from the gradient curves. The size of the specimens was measured before and after the treatment (at room temperature) and the change in size thus determined. After the treatment care was taken to make the size measurement in the center of the specimen in order not to include the increase in size due to expansion along the sides of the cylinders.

RESULTS

The amount of expansion is a function of the case depth and the time of treatment, so that in a general consideration of this expansion these variables must be included. In this paper the coefficient of expansion due to nitration is defined thus:

$$Kn = \frac{\text{Change in linear dimension}}{\text{Depth of the case}}$$

In the case of the cylinders, both ends expanded so the change in linear dimensions due to the nitriding of one face was

$$\frac{\text{Total change in linear dimension}}{2}$$

So that the coefficient becomes

$$Kn = \frac{\text{Total change in linear dimension}}{2\ (\text{Depth of the case})}$$

These coefficients were calculated for all of the specimens, and in curve number 2, they are plotted against the time of treatment. The zigzag curves show the results for the treatment at different pressures (as marked on the curve) with respect to time from 5 millimeters to 600 millimeters above atmospheric pressure. The smooth curve (Fig. 4) shows the average of all the other curves. The great deviation of some of the points from the average curve

is probably due to slight movements of the material in relieving the internal stresses which had not been relieved by the annealing before the treatment. Such slight variations of the total change in

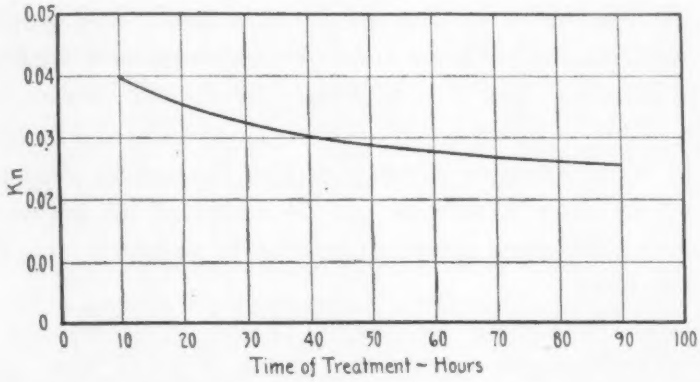

Fig. 4—Average Curve from Fig. 3 Showing the Relation Between Expansion Coefficient and Time.

linear dimension results in a large change in the coefficient when the case depth is small. These points exhibiting the greatest deviation occur where the time of treatment is short—which means that

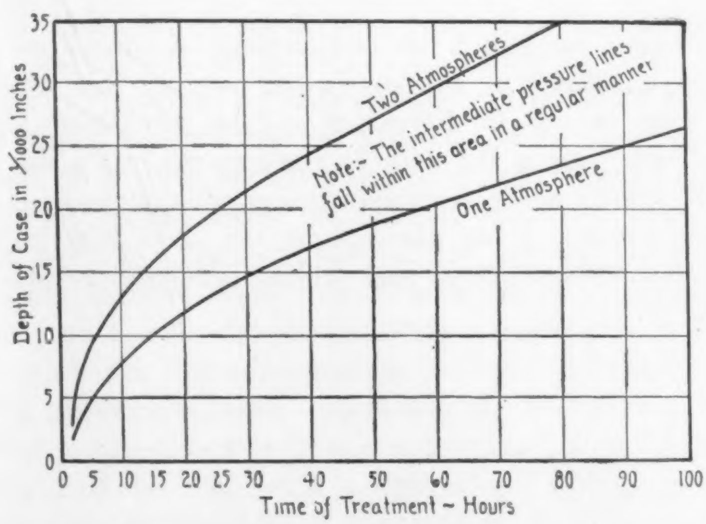

Fig. 5—Lines of Constant Pressure Showing the Relation Between Case Depth and Time at One and Two Atmospheres. Absolute Pressure of Ammonia. The Intermediate Pressure Lines Fall Within this Area in a Regular Manner.

the depth of the case is not great. The curves for the different pressures were all considered when the average curve was determined since the gas pressure did not seem to affect the magnitude of the coefficient in any regular way.

Use of the Curves

Since the coefficient is a function of the time of treatment, and since it is necessary to know the case depth and the coefficient in order to determine the change in dimension, and since further the case depth varies with the time of treatment and with the pressure of the ammonia gas it is necessary to use the two curves, Figs. 4 and 5, in order to make a calculation for the change in dimension. Thus, if it be desired to determine the change in dimension occasioned by treating a sample for 24 hours at an ammonia pressure of 600 millimeters above atmospheric pressure the following solution will hold.

Solution: Referring to curve (Fig. 5) treatment for 24 hours at 600 millimeters gives a case depth of 0.017 inch. And from curve (Fig. 4), treatment for this length of time gives a coefficient of 0.0335.

Then the change in dimension is

$$0.017 \times 0.0335 = 0.00057 \text{ inches}$$

and if this be a piece that has had surfaces produced on opposite sides (such as shafts or the specimens used in this experiment) then the total change in dimension will be two times this, which is 0.00114 inch. From the data on the experiments made this was noted to be 0.0011 which is extraordinary close agreement. Similar calculations made at many places, however, show very good agreement between the calculated and the experimental results.

HARDNESS TESTING

By H. M. German

Abstract

The following paper presents some of the newer ideas pertaining to Brinell, Rockwell and scleroscope hardness testing. Charts showing comparative hardness values of Brinell with Rockwell C, Rockwell B and scleroscope; and a brief description of the Vickers and monotron hardness testing machines are given.

SEVERAL methods have been presented to measure the hardness of steel. Among these may be mentioned the Keep drill test, which is actually more of a measure of machinability than hardness, the sclerometer or diamond scratch test, the Brinell ball indentation test, and scleroscope test and the Rockwell indentation test. To this list should be added the Vickers test and the monotron which have been introduced in this country during the year 1927. The three commonly used types of tester are the Brinell, the Rockwell and the scleroscope.

The Brinell method, which is recognized as the standard hardness test, was introduced by Dr. J. A. Brinell in 1900. This test is a measure of hardness by deformation. It is based upon the fact that if a hard spherical object is pressed against a softer material, that is held in a rigid position, the hard sphere will permanently deform or indent the softer material, if sufficient pressure is applied. In making a standard test a fixed pressure is applied on a hardened and polished steel ball 10 millimeters in diameter. For iron, steel and the harder metals 3000 kilograms is the standard pressure, while for the softer metals like lead and babbitt metal, a moderated pressure is used. To obtain the hardness number corresponding to the diameter of the impression, the diameter of the impression may be read with a microscope having a graduated millimeter scale or the depth of the impression taken by a micrometer attachment. The readings obtained may be referred to a chart

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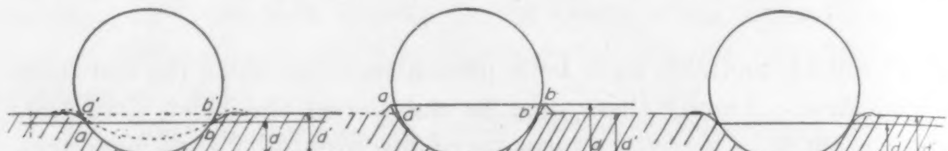
A paper presented before the semi-annual meeting of the society held in Montreal, February 16 and 17, 1928. The author, H. M. German, a member of the society, is metallurgist of the Universal Steel Co., Bridgeville, Pa. Manuscript received December 1, 1927.

which will transpose them to the corresponding degree of hardness or hardness number, or they may be calculated.

Honda and Takahasi[1] in their research "On the Indentation Hardness of Metals" show that Brinell's method of measuring the hardness of metals from the diameter of impression after the load is taken off, is not suitable, but that the diameter of impression should be measured under the full load. In soft metals, the hardness as measured by these two methods does not differ much from each other, but in hard metals, this difference is considerable. In hard quenched steels, the depression under load is about twice that



Figs. 1, 2, 3—Diagrams Showing the Effect of Deformation of the Surface of Material Under Test.

measured when the load is released. The difference is due to the elastic recovery of the material under test after the load has been removed and a piling up or depression of the metal around the impression. The curvature of the impression is the same as the ball when under load but when the load is removed the elastic recovery of the material is greater at the bottom of the impression than at the periphery, consequently the bottom of the impression does not retain it spherical shape but is somewhat flattened. This is illustrated in Fig. 1. The solid line represents the impression line under load and the broken line represents the impression line after the load is removed. The effect of the deformation of the surface of the material under test is also shown in Figs. 2 and 3. Fig. 2 illustrates the building up condition around the ball common with soft materials and Fig. 3 illustrates a depression next to the ball which changes to an elevation, which condition is common to hard materials. In Figs. 1 and 2 ab represents the true diameter of the impressions under load and a′b′ the observed diameters after the load is removed.

Brinell's scale is defined as the ratio of the applied pressure to the area of contact between the ball and the specimen. The hard-

[1]Dr. Kotaro Honda and Kirmoske Takahasi, Science Reports of the Tohoku Imperial University, First Series, Vol. XVI, No. 3, April, 1927.

ness number is calculated from the following formula:

$$H = \frac{P}{\frac{\pi D}{2} \left(D - \sqrt{D^2 - d^2}\right)}$$

H = the Brinell hardness number, P = the load applied, D = diameter of ball, and d = diameter of the ball impression.

d is taken as the observed diameter measured with a scale or micrometer microscope after the load is removed and is consequently not the true diameter. The Brinell test as at present conducted is not the hardness as measured by the ratio of the applied pressure to the area of contact between the ball and the specimen but is the hardness as measured by the ratio of the applied pressure to the area of contact between the ball and the specimen after the applied pressure has been removed. The depth of impression under load can be accurately measured with a depth gage and readily converted into the diameter of impression which will be the true impression, which only will give accurate results. As the amount of building up and depression around the ball varies with the hardness and class of material under test, it is evident that the present Brinell test is only comparative and not accurate. Steps should be taken to accurately define the Brinell test and the method for conducting it to obtain accurate results.

Other variables which influence Brinell readings are, the deformation of the ball under load, the accuracy of the pressure, the rate of application of pressure and the time the full pressure is applied.

The steel ball must be sufficiently hard that it will not deform permanently in tests. If the ball deforms under load, it will flatten at the points of applied pressure and produce a shallow impression which will give an inaccurate reading.

Investigations by Foss and Brumfield[2] and Mailander[3] show that the ordinary steel ball will give accurate readings only up to a Brinell hardness of 450, above this number the balls take a permanent deformation. Hultgren[4] has found that by cold working a

[2] F. E. Foss and R. C. Brumfield—*Proceedings*, American Society for Testing Materials, Vol. 22, Pt. II, p. 312, 1922.

[3] R. Mailander—*Stahl und Eisen*, Vol. 45, p. 1769, 1925.

[4] A. Hultgren—*Journal*, Iron and Steel Institute, September, 1924.

hardened and polished steel ball, the surface is hardened to a sufficient depth to enable the ball to withstand considerably greater pressure than an ordinary steel ball without deformation. Balls given the cold work treatment permit accurate tests on materials up to number 700 Brinell hardness. Quick and Jordan[5] made Brinell balls from an iron-carbon-vanadium alloy of the following analysis:—carbon 2.93 per cent, manganese 0.10 per cent, sulphur 0.016 per cent, silicon 1.55 per cent, and vanadium 13.5 per cent. The balls were heated to 1560 degrees Fahr., quenched in water, tempered at 212 degrees Fahr., ground, polished and work-hardened under about 2000 kilograms pressure per ball. Under tests, they showed no advantage over Hultgren balls for testing materials up to 700 Brinell. When testing materials up to 800 Brinell (approximately 65 Rockwell C) the permanent flattening of the iron-carbon-vanadium balls was about half the amount of the Hultgren balls. As the use of these balls is limited to testing steel of maximum hardness, their field is quite limited, and consequently their manufacture was not continued.

In order to obtain accurate readings, it is essential that the load be fixed and not subject to variation. Most of the variations are produced by a too rapid application of pressure causing overloading. However, if the machine is correctly calibrated and if the pressure is applied gradually, particularly when the full load is about reached, the danger of overloading is minimized. When using the hydraulic-type machine, it is considered good practice to raise the weights with the fingers just before the full load is reached and then lower them gently.

The effect of the rate of application of the load and the effect of the length of time the full load is applied was investigated by the Hardness Testing Committee of the American Society for Steel Treating and a complete report of the findings made at the Detroit convention. In this investigation, three samples of steel 4″ long by 3″ wide by 5/16″ thick were sent to each member of the committee. Sample number one was engraving plate steel, normalized and annealed to a Brinell hardness number of approximately 140; sample number two was a nickel-chromium steel, normalized, hardened and tempered to a Brinell hardness number of approximately 269; and sample number three was a nickel-molybdenum

[5]G. W. Quick and L. Jordan, TRANSACTIONS, American Society for Steel Treating, Winter meeting, Washington, January, 1927.

steel that was normalized, hardened and tempered to a Brinell number of approximately 510. After heat treatment, the samples were ground and polished. The following tests were prescribed.

A.—Effect of speed in applying the load. Apply the load uniformly from 0 to 300 kilograms in the following times: 2-4-6-8-10-12-14-16 seconds, release load immediately and take readings.

B.—Effect of speed in applying the load. Apply the load as in A, permit the full load to exert its force for 30 seconds, release load and take readings.

C.—Effect of time of application of full load. Apply the load uniformily from 0 to 3000 kilograms in 10 seconds, permit the full load to exert its force for the following times: 5-10-15-20-25-30-35-40-50-60-70-80 seconds, release load and take readings.

A summary of the results obtained in Test A show that greater irregularities were obtained with soft steel than with the medium hard and hard steels: also, that the times required to reach a point of equilibrium beyond which there is only a slight change in the depth of impressions are longer for soft steel than for medium hard steels. The minimum time for application to produce uniform results may be taken at eight seconds.

Test B showed that the holding time had a tendency to produce more uniform readings on tests in which the load was applied slowly but had no constant effect on the readings of tests in which the loads were applied rapidly as in two to four seconds. There is no doubt that a variation in results would be obtained if the rate of application was not uniform and acceleration occurred at the time of final attainment.

The results of test C show that there is a constant increase in the impression diameters from five to eighty seconds. This increase is most noticeable at the low times of application. Beyond a period of thirty seconds there is undoubtedly a slight flow of metal, but this amount is so small that it cannot be measured accurately with the instruments commonly supplied by makers of Brinell machines. For all practical purposes, the standard time of thirty seconds gives consistent results.

Fig. 4 shows a side and end view of an improved hardness testing machine[6].

This machine possesses several advantages over the usual types

[6]H. M. German—Standardizing the Brinell Hardness Test. TRANSACTIONS, American Society for Steel Treating, Vol. XI, No. 1, January, 1927, p. 54.

of Brinell machines, in that the rate of pressure application is fixed, the time of pressure application is fixed, the applied load is con-

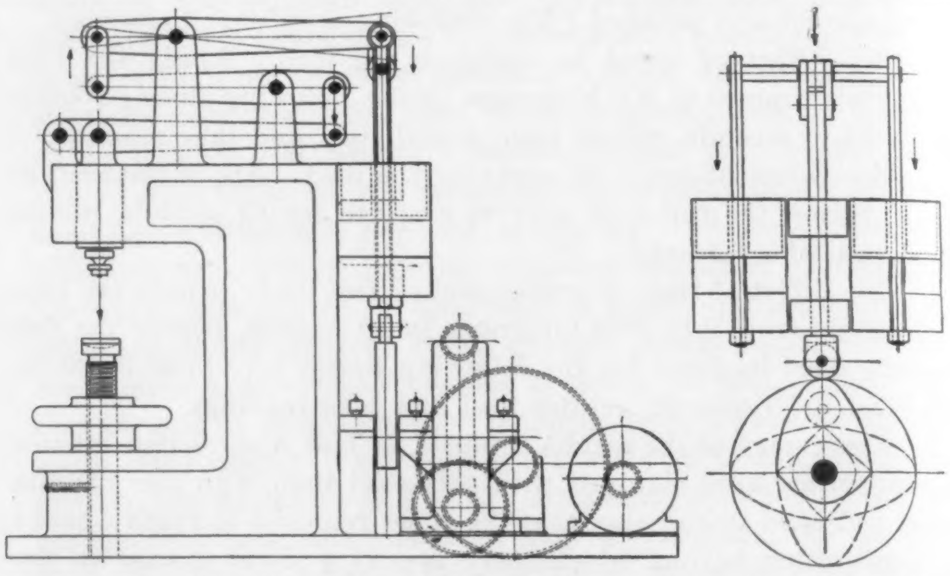


Fig. 4—Drawing Showing Side and End View of An Improved Hardness Testing Machine.

stant, the time of application of the applied load is fixed, and the rate and time for release of the applied load is fixed.

Rockwell Hardness Testing

Principle of Test. "The Rockwell tester[7] measures the depth of residual penetration by a ball, or cone, under fixed conditions of load. The hardness is expressed as a number which is derived by subtracting the penetration from an arbitrary constant. The greater the penetration, the lower the Rockwell number. A minor load of 10 kilograms is first applied, which seats the penetrator in the surface of the specimen, which is thus held in position. The dial is then set at zero, and a major load of 150 kilograms is added. (When using one-sixteenth inch steel ball in place of the diamond cone penetrator, the major load is only 100 kilograms.) The major load is removed after the pointer comes to rest leaving the minor load still on. The dial then reads Rockwell hardness directly."

Since the Rockwell is an indentation test, the same factors as were discussed under Brinell testing, such as the rate of applica-

[7]New data sheets on Rockwell Hardness Testing submitted to the Hardness Testing Committee by A. L. Davis on June 2, 1927. A. S. S. T. Handbook.

tion of the major load and the length of time the load is applied, will influence the results. The rate of application can be adjusted but the time the load is applied and the speed at which the major load is released is at the discretion of the operator. The standard time for applying the load is 5 seconds but if the test is made to roughly sort articles according to their hardness, the time may be lessened. A detailed description of the Rockwell test and the precautions to be observed in making the test are fully covered in the data sheets of the American Society for Steel Treating.

Scleroscope Hardness Testing

The scleroscope measures the height of rebound of a standard weight when allowed to fall by gravity from a fixed height upon the substance to be tested. When a very hard article, like a hardened steel ball or a diamond pointed hammer is caused to fall on a horizontal surface, the height of rebound is proportional to the resilience of the article on which the hard surface falls. If the article to be tested is very hard, only a little of the energy produced by the falling weight will be dissipated by indentation but will be almost entirely expended on the rebound. However, if the article tested is quite soft, considerable of the falling energy will be consumed in indentation and less in rebound.

A scleroscope will give comparative results only when testing articles of like composition under like conditions. This point cannot be made too emphatic. By like conditions is meant the same analysis, the same thickness, and the same surface condition as rough, ground or polished. Fig. 5 shows the effect of thickness of materials on scleroscope readings.

These curves show that a thin piece of steel of a given Rockwell hardness will give a higher scleroscope reading than a thicker piece having the same Rockwell hardness.

The effect of surface conditions on scleroscope readings is clearly illustrated in the finishing of cast steel temper hand saws.

Last operation	Scleroscope readings
Hardened and tempered	68-70
Rough ground on coarse wet sandstone	73-76
Fine ground on fine wet sandstone	75-78
Rough polish—No. 100 emery	78-80
Fine polish—Flour emery	79-81

Rockwell readings with a steel ball taken on the same saws show 115 to 117. The above examples emphasize the effect of thickness and surface condition on the hardness figures obtained with

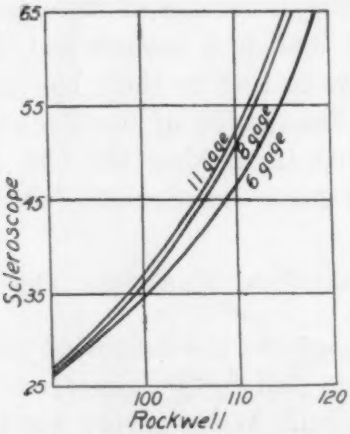


Fig. 5—Comparison Curves of Rockwell Steel Ball and Scleroscope Tests of Different Gages of Metal.

the scleroscope. A detailed description of the scleroscope test and the necessary precautions is given in the data sheets of the American Society for Steel Treating.

Comparison of Brinell, Rockwell and Scleroscope Numbers

Comparison curves Figs. 6, 7, 8 and 9 are taken from paper on "Relationships between Rockwell, Brinell and Scleroscope Numbers" by R. R. Moore which was presented before the Detroit convention of the society in September 1927 and published in the Transactions, Vol. XII, No. 6, p. 968.

A very complete and useful chart covering the comparison of Brinell, Rockwell and scleroscope hardness numerals has been submitted to the American Society for Steel Treating by J. H. Hruska, Danly Machine Specialties, Inc. This table will appear in the bound edition of the A. S. S. T. Handbook distributed to the membership during September, 1928.

Vickers Diamond Hardness Testing Machine

The Vickers machine, Fig. 10 is of the "plastic indentation" type, and resembles the standard Brinell machine in that it produces numerals that are identical to Brinell figures. Pressure is

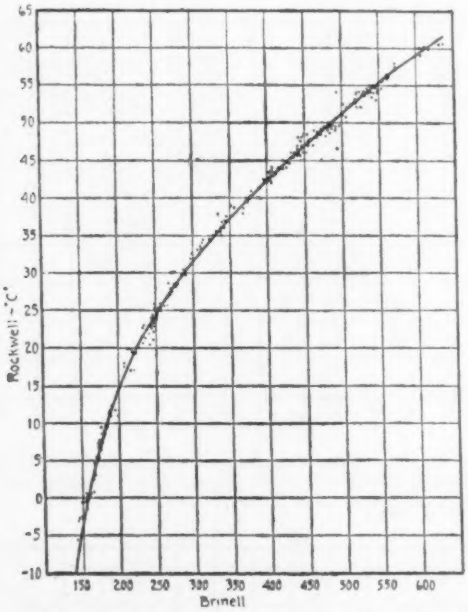


Fig. 6—Curve Showing Rockwell C–Brinell Relationships.—Moore.

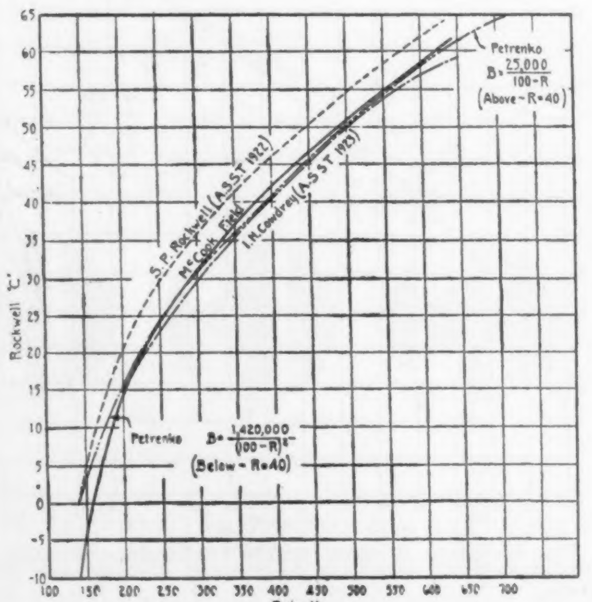


Fig. 7—Curves Showing Comparisons of Rockwell C–Brinell Relationships Observed by Four Different Investigators.—Petrenko.

applied through weights and levers, the standard load is 50 kilograms. By means of a cam and dash pot arrangement the pressure is applied slowly and gradually. The indentor is a diamond in the shape of a square-based pyramid having an included angle of

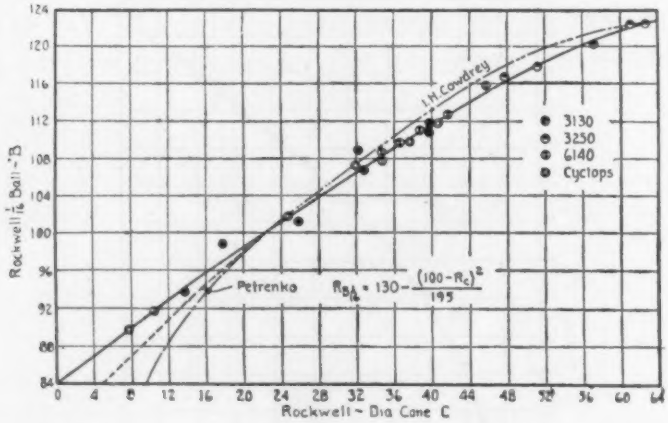


Fig. 8—Curves Giving Comparison of Rockwell 1/16 Inch Ball Reading Versus the Rockwell Diamond Cone Reading as Observed by Cowdrey, Petrenko and Moore.

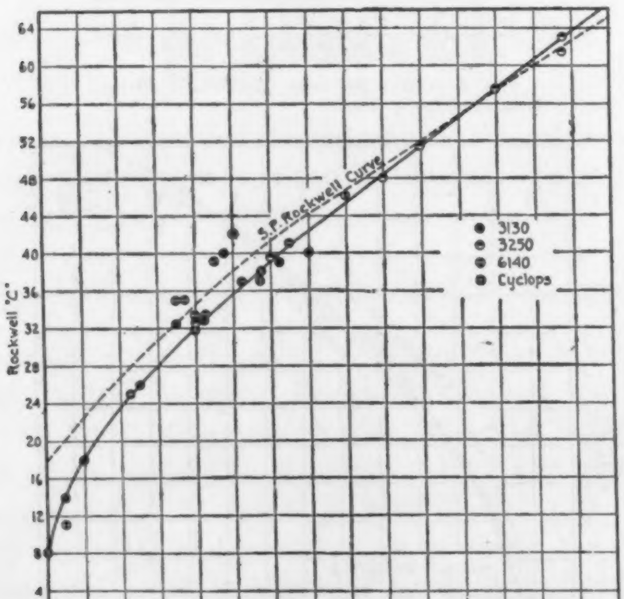


Fig. 9—Curves Showing Rockwell–Scleroscope Relationships, One Determined by S. P. Rockwell and the other by Moore.

136 degrees. Hardness is calculated as load divided by pyramidal area. After the pressure has been applied, the specimen is lowered and the diagonal reading is taken by means of a specially constructed micrometer which is fitted with knife edges instead of the usual hair lines. The reading is converted by means of tables directly to Brinell numerals.

In cases where the work has to be tested with a view of ascertaining whether it is within limits of specified hardness, a third knife edge is used. This third knife edge is set by means of the

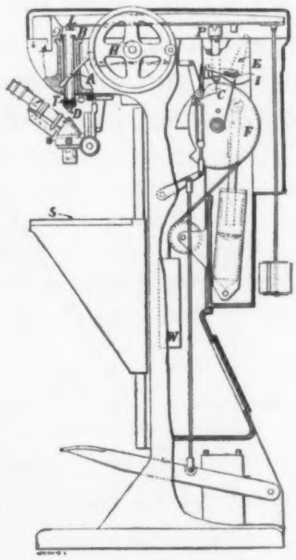


Fig. 10—Diagram of the Vickers Machine.

micrometer knife edge to correspond with the smaller dimension, i.e., the maximum limit of hardness, the micrometer knife edge then being adjusted to correspond with the larger dimension, i.e., the

Fig. 11—Readings as Observed on the Vickers Machine.

minimum limit of hardness. In reading it is only necessary to set the fixed knife edge to the left-hand corner of the impression in the ordinary way and the readings are observed as shown in Fig. 11.

This machine is very accurate and can be used on very thin material, as low as 0.006 inch by using lighter weights.

The Monotron

The monotron, invented by Shore, is called the constant diameter hardness indicator. It measures the amount of pressure neces-

sary to produce a fixed amount of indentation. The essential parts of the machine are—a diamond indentor having a spherical point $5/8$ millimeter in diameter; a dial depth gage for measuring the depth of indentation; a pressure gage for measuring the load to produce the indentation; and a hand lever for applying the load.

The machine is accurate and gives consistent results. It resembles a Brinell machine whose impression is measured with a

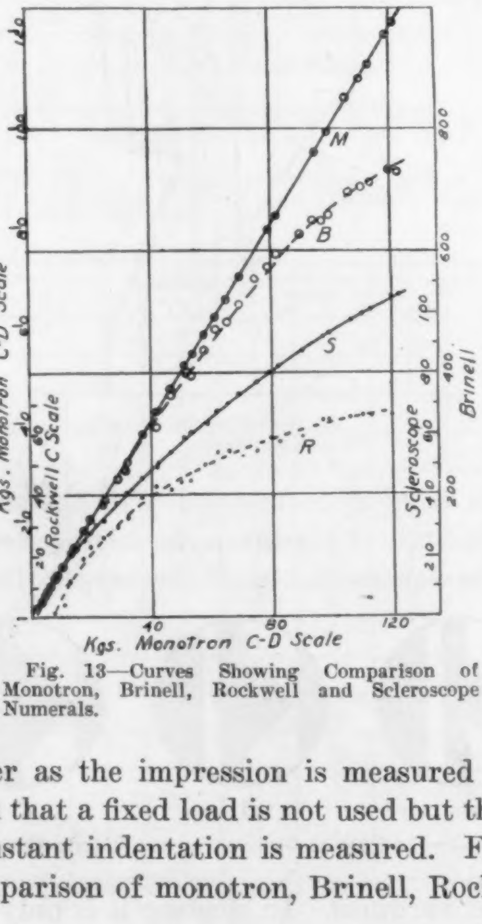


Fig. 13—Curves Showing Comparison of Monotron, Brinell, Rockwell and Scleroscope Numerals.

depth micrometer as the impression is measured under load and differs from it in that a fixed load is not used but the load necessary to produce a constant indentation is measured. Fig. 12 is a chart showing the comparison of monotron, Brinell, Rockwell and scleroscope numerals.

In concluding, the author wishes to say that all of the methods of testing that have been described are valuable. Some give results that are standard and others are comparative. However, if the basic principles of the tests are understood and if the necessary operating precautions are observed, consistent results can be obtained with all the methods.

A NOTE ON THE EFFECT OF HEAT TREATMENT ON ABNORMAL CASE CARBURIZING STEELS

By B. M. Larsen and A. W. Sikes

Abstract

Case carburizing steels may exhibit either grain-size abnormality or structural abnormality. Abnormal grain structures may be changed or modified by various heat treatments in the same way as in other steels. Structural abnormality, which involves a tendency toward the separation of ferrite and cementite in the hypereutectoid zone of the case, is not appreciably affected by heat treatment, even at temperatures around 2000-2050 degrees Fahr.

IN a comprehensive review of present knowledge concerning abnormal case carburizing steels recently published by Epstein and Rawdon (Preprint No. 6, American Society for Steel Treating, Winter Meeting, 1927), they state that two types of abnormality are to be found in low-carbon steels namely, "grain-size" and "structural." They further conclude that there is no known heat treatment which tends to make structurally abnormal steels more normal. The experience of most other investigators appears to substantiate this view, although there have been exceptions, the most recent being Sefing, whose work is reported in Bulletin No. 13, Sept., 1927, of the Michigan Engineering Experiment Station, East Lansing, Michigan.

Result of Sefing's Work

Sefing's results indicate that abnormal steels, after a suitable heat treatment, may be made definitely normal. The treatment that he found to have the most beneficial effect was heating the abnormal steel to the temperature range 2000 to 2025 degrees Fahr.

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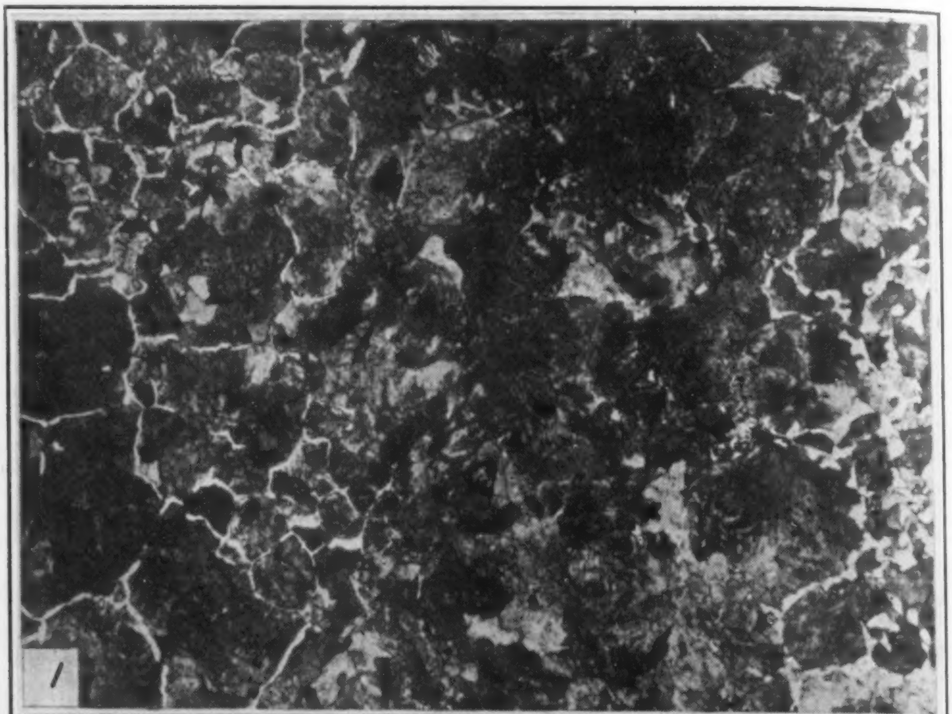
Of the authors, B. M. Larsen is assistant metallurgist, Pittsburgh Experiment Station and A. W. Sikes is research fellow at Carnegie Institute of Technology and United States Bureau of Mines, Pittsburgh. Manuscript received June 21, 1928.



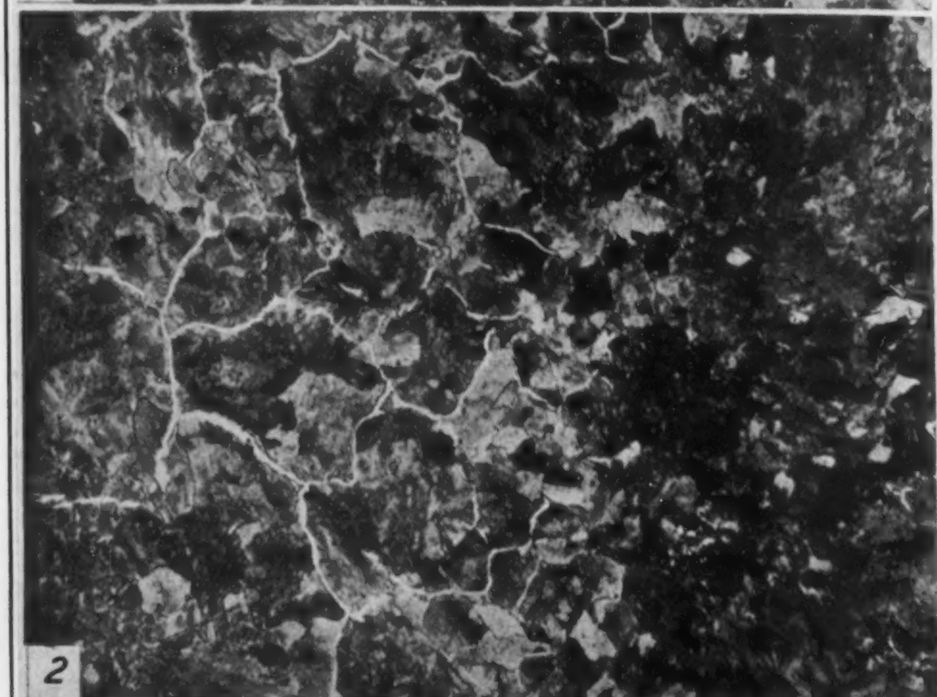


Fig. 1—Photomicrograph of Sample No. 1. No Heat Treatment before Carburization. Rating, Normal. Nital Etch. × 100. Fig. 2—Same Steel as in Fig. 1. Heated to 2015 Degrees Fahr. for 30 Minutes and Quenched in Brine before Carburization. Rating, Normal. Nital Etch. × 100.

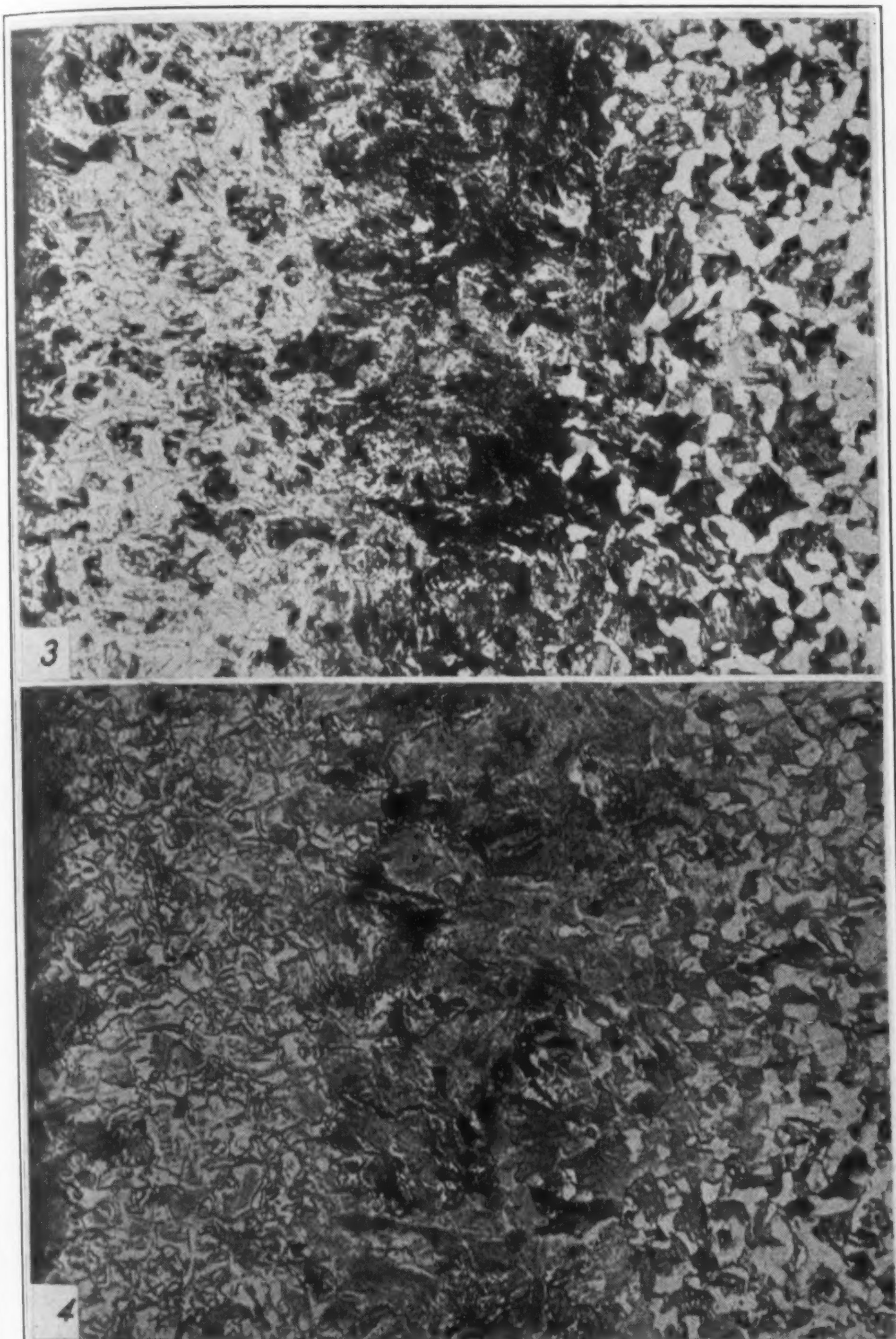


Fig. 3—Photomicrograph of Sample No. 2. No Heat Treatment before Carburization. Rating, Abnormal. Nital Etch. × 100. Fig. 4—Same Steel as Fig. 3. Heated to 2015 Degrees Fahr. for 30 Minutes and Quenched in Brine before Carburization. Rating, Abnormal. Nital Etch. × 100.

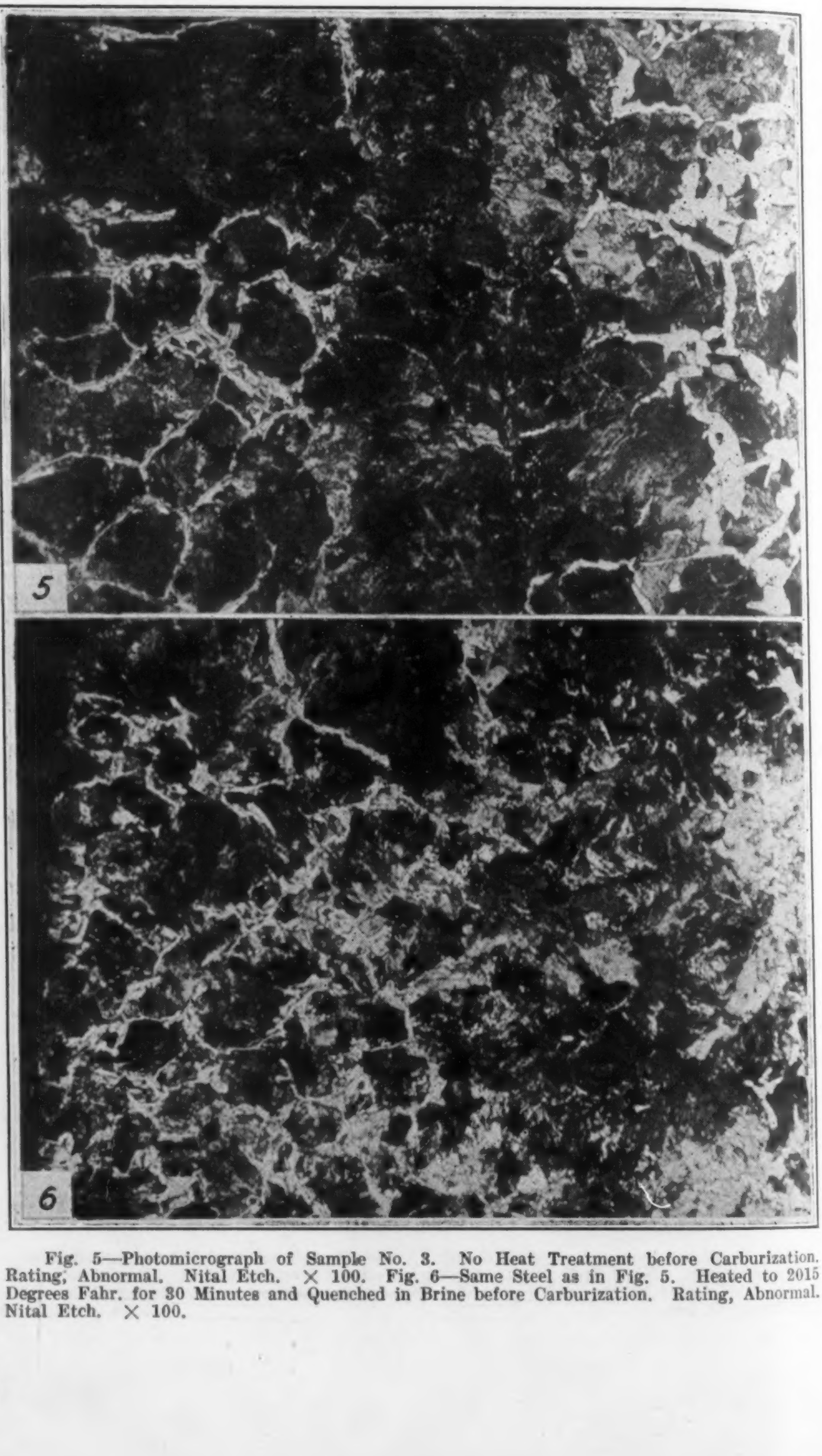


Fig. 5—Photomicrograph of Sample No. 3. No Heat Treatment before Carburization. Rating, Abnormal. Nital Etch. × 100. Fig. 6—Same Steel as in Fig. 5. Heated to 2015 Degrees Fahr. for 30 Minutes and Quenched in Brine before Carburization. Rating, Abnormal. Nital Etch. × 100.

and then quenching it rapidly in water. It is stated that this treatment, in all cases, resulted in a more normal structure in various samples of steels which in the untreated state appeared abnormal after carburization. In an attempt to duplicate these results the following series of tests was carried out at the Pittsburgh Experiment Station of the U. S. Bureau of Mines.

Effect of Heat Treatment on Abnormal Steel

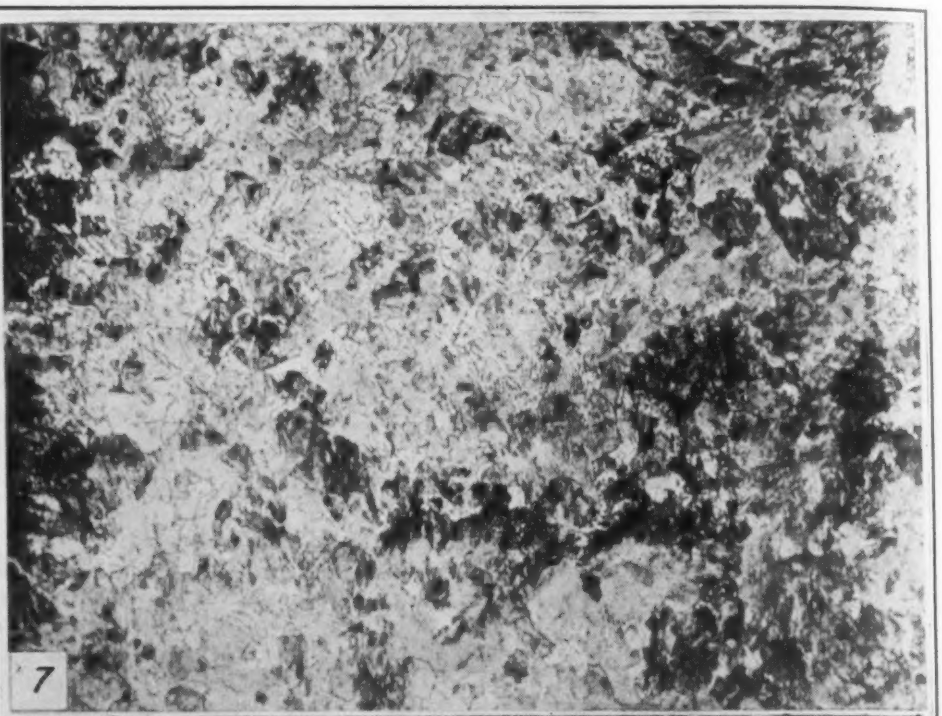
Five samples of low-carbon steel were selected for test. The table following gives their chemical composition and initial normality.

Table I
Per Cent Composition and Normality of Steels Tested

Sample	Carbon	Manganese	Silicon	Phosphorus	Sulphur	Structure
1	0.14	0.82	0.04	0.014	0.024	Normal
2	0.06	0.10	0.005	0.0142	0.017	Abnormal
3	0.09	0.375	0.004	0.018	0.023	Abnormal
4	0.08	0.40	....	0.019	0.029	Abnormal
5	0.08	0.43	....	0.017	0.030	Abnormal

The normal steel was used as a control. The other four samples showed various degrees of abnormality when subjected in the untreated state to the McQuaid-Ehn test *(Transactions,* American Institute of Mining and Metallurgical Engineers, Vol. 67, 1922, p. 341). Samples No. 1 and 2 came from steels made in a 300-pound laboratory electric steel furnace. Sample No. 3 was cut from a billet of commercial rimming steel, and Nos. 4 and 5 were from small, quickly cooled, ladle test samples of similar steel.

After treatment at 2015 degrees Fahr. (± 10 degrees Fahr.) for 30 minutes, followed by a rapid quench in a cold, saturated brine solution which had been boiled for 15 minutes to expel dissolved and occluded gases, the normality ratings from McQuaid-Ehn tests of the five treated steels were identical with those of the original untreated steels in each case. The accompanying photomicrographs show the structures, after carburization, in each set of test pieces. The normality ratings are based essentially upon the degree of structural abnormality, i. e., upon the extent of divorce of the pearlite, especially in the hypereutectoid zone.



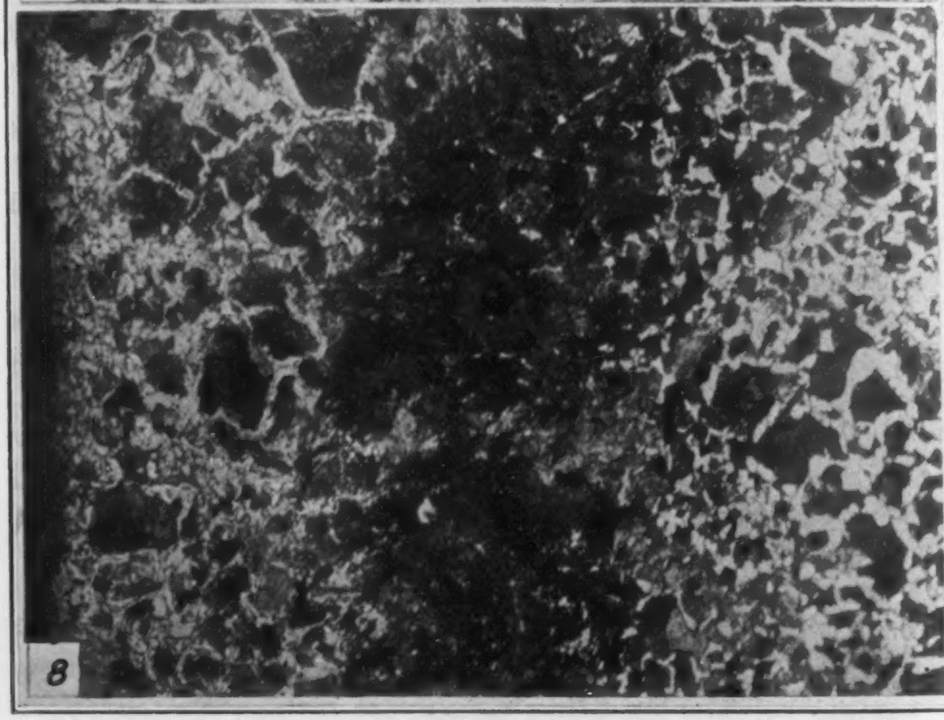


Fig. 7—Photomicrograph of Sample No. 4. No Heat Treatment before Carburization. Rating, Abnormal. Nital Etch. × 100. Fig. 8—Same Steel as in Fig. 7. Heated to 2015 Degrees Fahr. for 30 Minutes and Quenched in Brine before Carburization. Rating, Abnormal. Nital Etch. × 100.

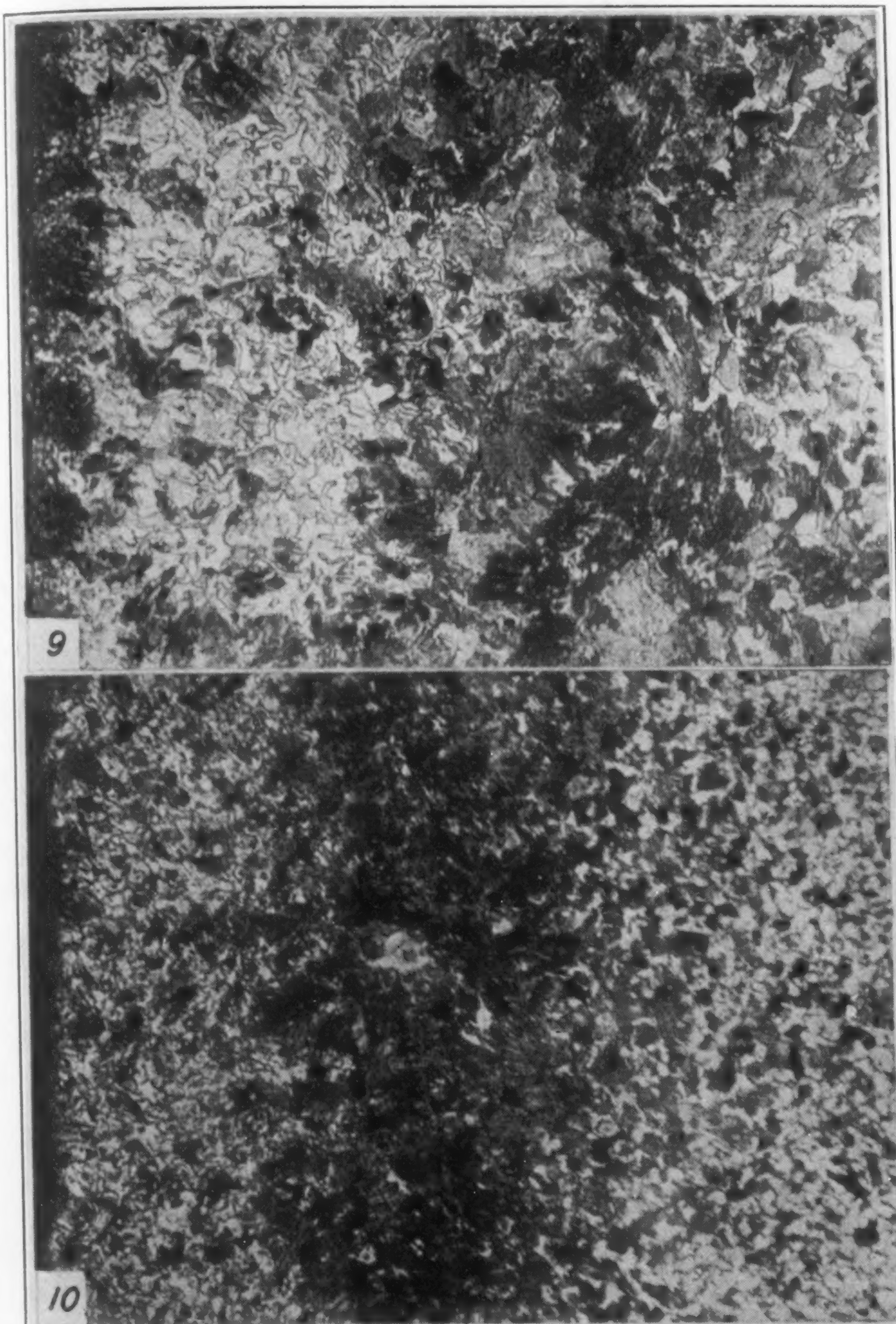


Fig. 9—Photomicrograph of Sample No. 5. No Heat Treatment before Carburization. Rating, Abnormal. Nital Etch. × 100. Fig. 10—Same Steel as in Fig. 9. Heated to 2015 Degrees Fahr. for 30 Minutes and Quenched in Brine before Carburization. Rating, Abnormal. Nital Etch. × 100.

It appears probable that the steels which Sefing reported upon were mostly of the type which are classified under "grain-size" abnormality. The steels that were treated by the Bureau of Mines displayed "structural" abnormality. As the former can be benefited by a suitable heat treatment, and the latter apparently cannot, care should be exercised in determining the classification to which the samples belong, because confusion may result by an improper realization of the condition of the steel.

Conclusions

1. Two types of abnormality in carburizing steels are possible; these are "grain-size" abnormality and "structural" abnormality.
2. A steel may display either, or both types of abnormality.
3. A suitable heat treatment may result in giving a more normal structure in abnormal steel having grain-size abnormality only.
4. Sefing's heat treatment, apparently, does not appreciably affect steels having structural abnormality.

ON THE NATURE AND APPLICATIONS OF THE PRINCIPAL TYPES OF TOOL STEEL

By W. H. Wills

Abstract

The development of the electric furnace and the aluminum reduction method for the manufacture of ferro alloys has increased the production of alloy tool steels and consequently there are now on the market hundreds of brands of tool steel. These brands may be largely divided into five types, carbon and carbon-vanadium, oil-hardening, high carbon, low tungsten, hot die, and high speed steels.

The various types of tool steel have been discussed individually in detail at various times but it is the purpose of this paper to discuss from a practical standpoint the structure and physical properties of each type of steel.

At the beginning of the present century the product of tool steel mills was limited to a few qualities of carbon steel, air hardening and low tungsten finishing steel. Then came the development of the electric melting furnace and the aluminum reduction method for the manufacture of ferro alloys. The quality of the alloys was much improved and the price reduced. This led to much more extensive experimental work in the manufacture of alloy steels and at the same time the applications multiplied and standards of production rose to higher levels. As a result of this growth and development there are now several hundred brands of tool steel on the market.

These numerous brands can be largely included under five divisions or types, namely, carbon and carbon-vanadium (water hardening), oil hardening (comprising manganese open-hearth nondeforming and high carbon chromium types), high carbon low tungsten finishing steels, hot die steels, and high speed steels. Several of these types have been covered individually in various papers before this society. However, our purpose is to discuss the

A paper presented before the St. Louis and Indianapolis chapters of the society. The author, W. H. Wills, a member of the society is metallurgist with the Atlas Steel Corp., Dunkirk, N. Y. Manuscript received May 25, 1928.

nature of these steels from a practical rather than a theoretical standpoint and how they fit in on various applications.

The term nature as applied to a grade of steel takes in a number of factors of which the outstanding include the structure and physical properties developed by various heat treatments. The five types differ so much in this respect that a single statement defining their physical properties is rather difficult. The degree of hardness developed by various treatments has an important bearing in each case. With carbon steels depth of hardness penetration, degree of toughness or impact value and in some cases change of size in heat treating are things to be considered. In case of the oil hardening die steels, resistance to wear, change in size and machinability are important. Hardness and resistance to abrasion, also ability to hold a keen cutting edge characterize the high carbon low tungsten group. The hot die steels have the property of retaining their hardness at elevated temperatures combining with this resistance to heat checking and shock. The high speed steels combine a high degree of hardness with wear resistance not only at ordinary temperatures but up to temperatures approximating 1000 degrees Fahr.

The question might be asked as to what has been responsible for making possible these types of steel which serve their purposes so well and represent such a variety of properties. The fundamentals are analysis or composition and heat treatment, so in brief we may say that the ferro alloys and the science of heat treating are the underlying factors. It should be borne in mind that the chemical specifications which these types represent and also the treatments were not discovered all at once, but are the result of the joint experience of steel maker and user over a period of years.

In taking up these five classes of tool steel we will first deal with the original and simplest type—carbon tool steel. Despite the increasing use of alloy tool steels straight carbon steel continues to hold its own and is more general in its uses than any other type. In fact there are few operations upon which carbon tool steel cannot be used and give some kind of results if properly handled. This grade depends on carbon alone for its hardening properties although small amount of manganese and silicon and the impurities phosphorus and sulphur are always present. Traces

of alloys such as chromium may exist at times, and if not in excess of 0.10 per cent are not apt to cause difficulty. In excess of this amount the depth of hardening is increased and this may affect the heat treatment of certain kinds of tools.

Carbon Steels

Chemical specifications for carbon tool steel generally allow a 10-point range for carbon and the ranges run from as low as 0.65 to 0.75 to 1.40 or 1.50 and over. Carbon contents of 0.80-0.90 and 0.95-1.05 per cent are the most common ranges for general uses. The usual limits on the other elements are manganese 0.20 to 0.30 per cent and up to 0.40 per cent maximum, phosphorus and sulphur 0.025 to 0.030 per cent maximum, silicon 0.10 to 0.30 per cent.

Carbon tool steel requires a drastic water quench to develop the desired degree of hardness in the great majority of cases. The instances are few where a milder oil quench is to be preferred. It can be treated to develop practically as high a degree of hardness as any other grade. However, the hardening range that gives a refined fracture is limited and grain growth sets in with moderate overheating. Except in small sections carbon tool steel after properly quenching shows a hard case usually of $\frac{1}{16}$ to $\frac{1}{8}$ depth and a soft core. The depth of hardening is affected by the severity of the quench and alloy content. Our experience has been that carbon content and heating above the regular hardening range have little effect on depth. It is readily apparent that on dies and tools redressed by grinding, the number of regrinds is limited by the depth of the case. On account of the rather severe quench required to develop the hard case, large sections must be carefully handled as regards uniform heating, avoiding scale, and agitation of the quenching bath. Open fire hardening is the general rule with the larger sections while with production work on small parts lead or salt baths are used to advantage.

Carbon tool steel loses its hardness with lower tempering temperatures than the alloy steels. The change up to the 300 to 400-degree Fahr. range is slight but above this comparatively rapid. It is this property that excludes its use for applications where hardness is required at more elevated temperatures.

The retention of the soft core after heat treating has its advantage where the application calls for resistance to shock or impact and it is this that makes straight carbon steel superior to the deeper hardening alloy steels for a number of purposes.

On account of requiring rather drastic water quenching, warpage and relatively large change of dimensions in hardening are often problems with this grade. The skill of the hardener and good heat treating equipment are highly important in working out their solution.

After thus recalling these properties of carbon tool steel as a type let us consider a few characteristic applications where it continues to hold its own. One of the foremost of these is chisels—hand and pneumatic. This might also include blacksmith tools and rivet sets. There are numerous alloy chisel steels on the market but our experience has been that carbon is widely used having the advantage of low price and fair performance. Certain pneumatic tool parts and rock drills account for considerable tonnage.

For cold header dies, many users find the straight carbon analysis unsurpassed. This is an application where a deep hardening steel nearly always fails by splitting or spalling off in service. The tough core enables the straight carbon steel to withstand the shock. The greatest outlet for this grade is doubtless for the varied applications where the cost of the steel is a factor and production secondary. This is a large subject in itself and space will not permit going into detail.

There is another water hardening steel that is closely allied to straight carbon in its properties. This is the carbon-vanadium type. It will develop a high degree of hardness but, being used mostly where less hardness and great toughness is required, it is very often tempered considerably after quenching. It has the advantage of a remarkably wide hardening range owing to the fact that the vanadium resists grain growth. As regards depth of hardening it behaves just like straight carbon steel. Resistance to shock and fatigue is its most important feature.

Oil Hardening Nondeforming Steels

As die work grew more complex and exacting, the need for a

steel that would be less subject to warpage and deformation than carbon steel became pronounced. This led to the development of one of the first alloy tool steels—usually known as the manganese oil hardening, nonshrinking, or nondeforming type. The analyses made by the different manufacturers vary somewhat but all carry approximately 0.85 to 0.90 per cent carbon. Manganese is the chief alloying element and ranges from as low as 1.00 to 1.50 per cent or more. In some cases small amounts of chromium and tungsten are carried, also vanadium and molybdenum. It is the manganese that confers the oil hardening property and as a result of the more gentle oil quench fewer hardening checks and less warpage are met with.

Being of eutectoid composition the simple carbon-manganese steel hardens at a comparatively low temperature. This is very desirable as the lower it is the less the scaling and change of dimensions. With manganese as the only alloy, the temperature range for proper hardening is limited. It is mainly to widen the hardening range from which a refined fracture can be obtained that additions of other alloys have been made. At the same time this has meant that the steel has to be quenched from a higher temperature to develop full hardness.

When properly hardened in oil this type will become file-hard in any ordinary sized sections. Its maximum hardness thus treated is a few point less than carbon water-quenched steel. It will harden as deep as any of the low alloy steels although probably not as deep as high speed steel. It absorbs heat slowly and the practice of preheating slowly to a dull red (1100 to 1200 degrees Fahr.) and transferring to another furnace at the hardening temperature is to be commended. On account of the lengthy heating periods used with this steel, good control of furnace atmosphere is desirable and oxidizing conditions either in a fuel or electric furnace should be avoided.

In tempering after quenching there is practically no change in hardness up to 350 to 375 degrees Fahr. At 400 degrees Fahr. there is a slight lowering which becomes more pronounced as 500 degrees Fahr. is reached and there is a steady falling off above that. This type has a low resistance to impact or shock—which, of course, is to be expected with its deep hardening property. Furthermore, its applications require a high degree of

hardness as a rule, so that tempering temperatures are seldom over 425 to 450 degrees Fahr.

The behavior as regards change in dimensions is of special interest. It should be remembered that any tool steel will show some change of dimensions after hardening. In the case of a straight piece there will be expansion on quenching. Contraction sets in with low temperature tempering treatments followed by slight expansion and then contraction as the tempering temperature is increased. In the case of an annular piece such as a ring die some contraction generally occurs depending on the sizes. With the manganese type, after quenching, a tempering treatment at about 400 degrees Fahr. results in the nearest approach to the original size at the same time holding proper hardness. At 500 degrees Fahr. expansion takes place. The linear expansion is considerably increased as the hardening temperature is raised which emphasizes the importance of close control in hardening. Tempering in a bath or electric furnace is much to be preferred to tempering to color on a hot plate. The nature of manganese oil hardening steel thus described makes it the ideal type for plug, ring and thread gages and for all kinds of intricate dies and other tools not subject to heavy shock.

One of the more recent alloy steel developments is a type that can really be included under the head of oil hardening nondeforming steels. This is the high carbon high chromium type carrying usually 2.00 to 2.50 per cent carbon and from 10 to 15 per cent chromium. Sometimes small amounts of other alloys are included. Carrying a high alloy content, its structure resembles that of high speed steel and it is even more difficult to forge. It absorbs heat slowly and due to the numerous carbides that have to be taken into solution for proper hardening, should be held for considerable time at the hardening temperature before quenching. For these reasons pack hardening the steel is the best practice, in order that slow heating is insured and the surface is protected during the long time at heat. Oil quenching is the rule with this type, and it will develop a high degree of hardness when quenched from a fairly wide temperature range. Hardness values as high as 66 to 67 Rockwell can be obtained with rather heavy sections. It is important to avoid too high hardening temperatures because when 1750 to 1800 degrees Fahr. is exceeded, in place of obtaining

a fully martenstic structure, a mixture of martensite and austenite is formed. More and more of the latter is formed with higher hardening temperatures until when quenched from around 1950 degrees Fahr. the structure is entirely austenitic. When this condition is obtained the tool will test soft, between 40 and 45 Rockwell, yet hard to the file. There will be considerable shrinkage and the piece will be nonmagnetic. The fracture becomes rather open.

In tempering this steel the falling off in hardness is gradual as compared to the low alloy steels. Even with a 1000-degree Fahr. temper a hardness of over 50 Rockwell is maintained. Above 1100 degrees Fahr. the lowering of the hardness is more pronounced. A rather peculiar condition arises when the steel has been given a high quench so as to develop an austenitic structure. The hardness will remain unchanged (approximately 40 to 45 Rockwell) with tempers up to 900 degrees Fahr. At 950 to 1000 degrees Fahr. there is a sharp rise in hardness to more than 60 Rockwell,—the result of the break-up of the austenite into martensite. The falling off is just as rapid when these tempering temperatures are exceeded.

The high carbon high chromium type as might be expected is a deep hardening steel and may be counted on to harden through any section of ordinary size. It is to some extent air hardening. The toughness or impact value of this type is low as compared to straight carbon. This is, of course, a measure of its transverse strength across the grain or direction of the carbides and is a point that should be borne in mind in designing tools of this grade. It is harder to machine than the manganese type but when properly annealed should work about like high speed steel. When fully annealed, the Brinell hardness runs 228 to 248.

The steel is distinguished by its remarkable resistance to abrasion and wear. This along with its nondeforming property which compares favorably with the manganese type, make it unsurpassed for die work where high production is of first importance.

The applications to which this steel has been put are of interest on on account of their variety and the economy effected through the high rate of production obtained. One of the first uses was for wire drawing dies. It has to a certain extent replaced chilled iron for this purpose. Dies on this work are hardened and given a

high tempering treatment to approximately 512 Brinell or 52 Rockwell. They are then soft enough to ream to a larger size, yet hard enough to give a good run.

For drawing bars of various shapes it is generally in the form of a punched or sectional die and used in the semiannealed condition without hardening. The hardness desired is approximately 325 Brinell, which is soft enough for machining and sufficiently hard for the production required.

The use of this type of steel for blanking and cold forming dies is perhaps its most general application. The material worked ranges from light gage silicon sheet steel to $\frac{3}{16}$-inch plate. One manufacturer has run extensive comparative tests between this type of die steel and straight carbon steel on silicon sheets having a thickness of 0.019 to 0.025 inch. These results show a 3 to 1 production over the straight carbon steel and a die cost per million cuts approximately 40 per cent of that with straight carbon steel. Another concern reports a 2 to 1 production over high speed steel on similar work. Where high production is of first importance this type is unequalled. This steel has been adopted for a number of roll applications usually replacing straight carbon. One of the more important of these is the rolling of automobile rim stock. Another is for the rolling of steel wire into strip in the manufacture of flexible conduit. A very exacting use is for rolling tinsel or braid from fine wire. Gold wire has been rolled as small as 0.003 inch wide by one-half of a thousanth inch thick. Rolls for this purpose must be treated for the maximum hardness and must show a perfect surface after grinding.

Mention might be made of some of the minor applications such as thread rolling dies, broaches, burnishing and trimming dies, and dies for forming clay or porcelain. In several shops it has worked out well on brass forming and seating tools, although this use is not general.

High Carbon Low Tungsten Finishing Steels

Our next division takes in the high carbon low tungsten finishing steels. Most of the manufacturers furnish two grades coming under this head. One of these often known as a tap steel usually containing carbon from 1.15 to 1.25 per cent, tungsten 1.50 to

2.00 per cent, with small amounts of chromium and vanadium. The other, primarily a finishing steel, runs higher in carbon (1.30 to 1.40 per cent) with 2 to 5 per cent tungsten and in some cases small amounts of chromium and vanadium.

These steels are either oil or water hardening but to develop the extreme hardness of which they are capable, a water quench is preferred. Tools of small section, however, will get sufficiently hard for most purposes with an oil quench. With a water quench a Rockwell hardness of 67 to 68 can be obtained. Due to the tungsten content, the hardness holds up better than straight carbon steel for a given tempering temperature and a keener cutting edge is maintained. This is their chief advantage. They are deep hardening and have a low resistance to shock or impact.

Having these characteristics they find their use where extreme hardness is required with little or no shock, such as for taking finishing cuts on chilled iron, steel or brass. When given an oil quench the deformation is light and they are used in a number of places where the manganese oil hardening type would apply. However, on account of the higher hardening temperature required when quenched in oil the change of size is necessarily greater than the manganese steel.

The most common applications are for taps and threading tools, broaches, rotary slitting cutters, reamers and lathe tools for light cuts on chilled iron.

Hot Die Steels

Our next class takes in the hot work or hot die steels. The principal requirements are: first, ability to retain a fair degree of hardness at elevated temperatures so as to resist wear, as parts of the dies in contact with the stock attain a dull red heat at times; second, ability to withstand shock, as a forging operation is oftened involved; third, ability to resist heat checking the result of rapid changes of temperature causing alternate expansion and contraction in service. For this kind of work two types have come into general use—a chromium steel carrying around 0.80 to 0.90 per cent carbon and 3.50 to 4.00 per cent chromium and a tungsten steel with approximately 0.30 to 0.45 per cent carbon, tungsten 10 to 14 per cent, chromium 2 to 3 per cent and in some cases a small amount of vanadium.

The chromium type is capable of developing a rather high degree of hardness, particularly if the die is small and an oil quench is used. The practice of cooling in an air blast is commonly used in which case the parts are brought up to somewhat higher temperature 100 degrees or more above that used when quenching

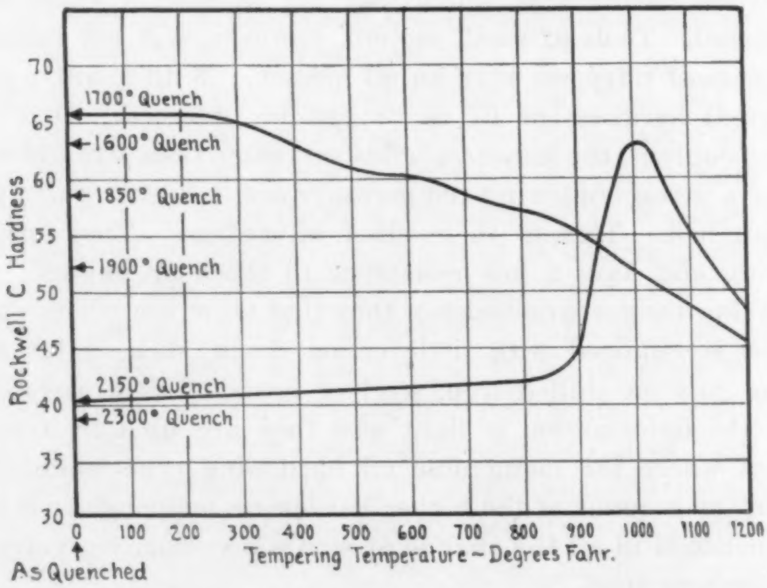


Fig. 1—Curves Showing Variation of Hardness of High Carbon, High Chromium Die Steel with Various Treatments.

in oil. In this case the degree of hardness attained is less, yet it is generally more that what is required for the dies going into service. The size of the die of course has quite a bearing on the hardness as quenched. While developing moderate hardness, less than straight carbon, and the low alloy steels, it retains it in a fair measure after much higher tempering temperatures than these other grades. Most applications require that the steel should be as soft as 45 to 50 Rockwell or around 400 to 450 Brinell and this often calls for tempering as high as 900 to 1000 degrees Fahr. With tempering treatments at 1100 degrees Fahr. or over the falling off in hardness is more rapid.

Though the chromium type is deep hardening it has a good resistance to impact or shock when heat treated to the above mentioned hardness values. When treated for greater hardness such as around 55 or 60 Rockwell the impact value is much less and breakage is apt to occur when the dies are subjected to shock.

It is therefore a great advantage to work to a definite hardness with hot die steels and check the hardness carefully before the dies go into service.

The tungsten hot die steels are hardened in oil or air but require higher temperatures ranging from 1900 to 2100 degrees

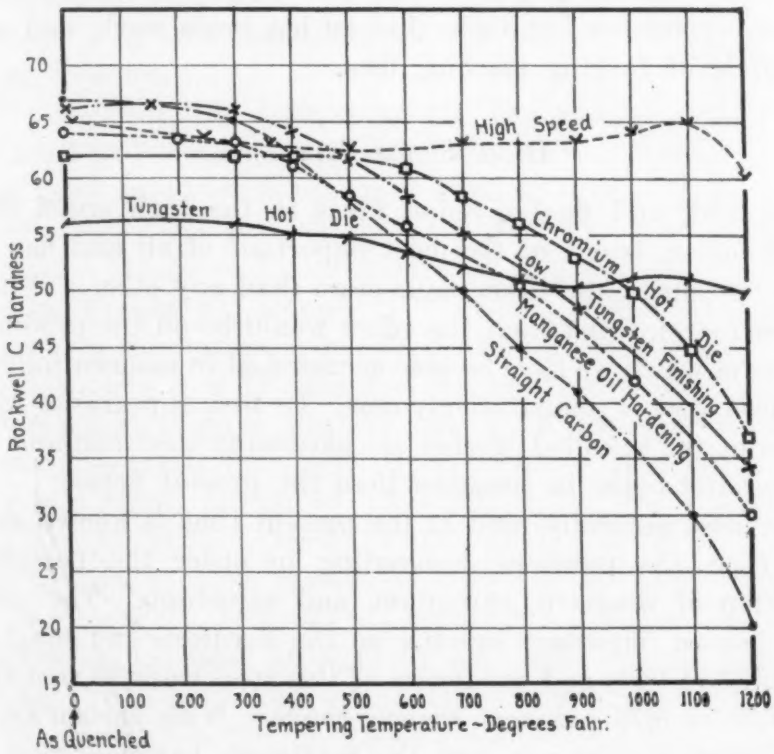


Fig. 2—Curves Showing Variation of Hardness of Tool Steels with Various Tempers.

Fahr. or more. The hardness as quenched is less than that of the chromium type and commonly runs 50 Rockwell or a little over, or Brinell 450 to 500. However, a higher hardness is maintained as the tempering temperature is increased and in fact there is little falling off up to 1200 degrees Fahr. This, of course, makes the tungsten steel superior to the chromium type on severe service where subject to especially high heat. Its impact value is also greater. On the other hand, due to its high tungsten and chromium content it is more apt to crack after sudden changes of temperature and water cooling should be applied carefully. The chromium type is more fool proof in this respect.

The chromium type of hot die steel seems to be the more popular with the bolt and rivet manufacturers for hot header and gripper dies. The tungsten type being more expensive requires a considerably higher average production to justify its use. The tungsten steel, however, is widely used and finds its field where operating conditions are severe as on hot punching or shearing jobs, for certain hot nut tools, dies on hot brass work, and many other kinds of forging machine dies.

High Speed Steels

Our fifth and final division takes in the high speed steels. This, of course, is one of the most important of all and has been covered by papers and discussions more than any other. Without high speed steel, think what the effect would be on the production schedules to which we have become accustomed in modern industry. High speed steel is comparatively new. Its first appearance was in the form of the so-called Mushet air hardening steel running high in carbon and lower in tungsten than the present types.

The most generally used at the present time is known as the 18:4:1 type, the numbers designating in order the percentage composition of tungsten, chromium, and vanadium. The carbon content has an important bearing on the hardness and toughness of the finished tools and producers of this steel work to something like a 0.60 to 0.75 per cent carbon range. With carbon on the low side toward 0.60 per cent the maximum hardness that can be developed is not as great as with carbon in the 0.70 per cent range. On the other hand the toughness is somewhat greater with the lower carbon material. The present tendency is to run the carbon and vanadium contents on the high side for cutting tools.

Brief mention will be made of the other high speed types which are used to a lesser extent. First there is the cobalt steel containing tungsten, chromium, vanadium on the high side of the regular specification and 3 to 5 per cent cobalt. In a few instances molybdenum is present up to about 1 per cent. Cobalt appears to aid in maintaining the cutting edge at or near a red heat and improve wearing qualities. A point to remember, however, is that the steel hardens with a soft skin so that its use is limited to tools that can be ground all over after treating.

There is also a specification with 0.80 per cent carbon or more, tungsten and chromium normal, vanadium 1.50 to 2.00 per cent and molybdenum 0.50 per cent. This grade has given very good results on production cutting where not subject to shock.

The 14:4:2 type is on the market as a general-purpose high speed steel and a similar specification with lower chromium and low vanadium finds some use for taps and reamers having the advantage of a lower hardening temperature with less distortion in heat treatment.

We are doubtless all familiar with the heat treatment of high speed steel and the general practice of a slow preheating followed by the more rapid bringing up to the high temperature required in hardening. Open fire heating is the most widely used, salt baths to a limited extent, and pack hardening in a few cases. The high tempering treatment, around 1100 degrees Fahr. is almost universal where maximum hardness and cutting qualities are required.

High speed steel as quenched develops a high degree of hardness but not quite up to straight carbon. However, as the tempering temperature is increased the hardness is very little altered. There is a slight falling off from 500 up to 900 degrees Fahr. From 1050 to 1100 degrees Fahr. there is a slight increase bringing it up to and in some instances above the initial hardness. At 1150 degrees Fahr. and over a decrease is noticeable. This ability to retain its hardness at elevated temperatures is the most outstanding property of high speed steel. It is very deep hardening and the usual quenching mediums are either air or oil. As might be expected the toughness or impact value is low especially when heat treated for high degrees of hardness. Quite a number of applications require more toughness and less hardness. In these cases steel of lower carbon content can be applied and a higher tempering treatment given.

On account of the high temperatures required in hardening, dimensional changes of high speed steel tools are greater than the so-called nondeforming die steels. However, by careful regulation of temperatures, time factor and furnace atmosphere these can be held within reasonable bounds.

The application of high speed steel is a good sized subject in itself. The 18:4:1 type leads all the others by a wide margin in quantity used. It is standard with a great many of the manufac-

turers of twist drills, reamers, taps, dies, and milling cutters as well as with the majority of large concerns using it in their own production work. For general shop tools—lathe, planer, shaper, etc.—working on all kinds of material it is most satisfactory. There are numerous punch and die applications where high speed steel has done very well as compared to carbon or the other die steels. Also it overlaps with the hot die steels in some instances as on certain hot punching and forming and extrusion dies. These cases call for steel with carbon on the low side and special heat treatments to produce the necessary toughness.

It is on the difficult cutting jobs particularly where the maximum of production is looked for that some of the special high speed steels are resorted to. The cobalt high speed steels give excellent performance on cast iron and steel castings where hard spots, scale and sand are apt to be encountered. It also stands up well on heat treated alloy steel and the alloy iron rolls such as Adamite, Phoenix metal, etc.

The high carbon molybdenum type has performed better than the 18:4:1 type on screw machine work and turning jobs where the cutting speed is high and the tools are not subject to shock.

We have thus reviewed the five principal types of tool steel and in concluding it might be in order to mention something about future developments. The tool steel industry believes strongly in research and development work not only to improve present products but to bring out new steels that will give better performance. On the other hand, industry is requiring more and more from tool steel. Particular instances of this are high speed steel for tools on automatics, drills, and milling cutters. Better die steels are wanted for cold and hot heading machines. The same applies for many hot and cold forming operations. These problems will receive best attention only by the steel maker and user continuing to work together and making use of their combined experience.

HEATING OF STEEL BY THE CONTROLLED TEMPERATURE METHOD

By G. W. Hegel

Abstract

The purpose of this paper is to demonstrate the effect of the rate of heating through the critical range on the temperature distribution in a piece of steel.

It also shows how the best results can be obtained by controlling the maximum temperature.

A NUMBER of methods for the heat treatment of steel are in use or have been proposed, some of them employing instruments to indicate the critical point or to produce a graphic record as the piece is being heated. These instruments use the physical change at the critical point as a means of indication, such as loss of magnetism, change in volume, or change in the rate of temperature rise while absorbing the heat of transformation.

The production of heat treated parts has increased at an enormous rate in recent years, and it is hardly practicable to heat treat large quantities of material by the methods outlined. Most of this material is being handled in either box-type or continuous furnaces, the temperature of which is held constant by automatic control apparatus, at a value somewhat above the critical temperature.

The amount that the temperature is held above the critical temperature, or the "gradient," will determine the total time required for heating, and the rate of heating through the critical point. The proper rate of heating has been the subject of much discussion, and it is generally agreed that heating should be done as slowly as practicable, and particularly through the critical range on account of the strains that are likely to be set up.

Interest in this subject has led the writer to undertake a series of experiments to determine the effect of different temperature gradients on the rate of heating of regular and irregular sections.

While most of the strains occurring in hardened steel parts are due to rapid quenching, this condition is aggravated by stresses

The author, G. W. Hegel, a member of the society, is engineer with the General Electric Co., Schenectady, N. Y. Manuscript received March, 1928.

set up by unequal heating while in the furnace. No attempt is here being made to prove which is the more serious. We will, however, illustrate how the rate of heating through the critical range will affect the uniformity of temperature in both irregular and regular sections.

It is well known that a piece of steel, while being heated through the critical range ceases to expand and actually contracts

Fig. 1—Photograph of Blanking Die Used for Determining Rate of Heating in Large and Small Sections.

before beginning to expand again at a new rate. Instruments are on the market which determine the critical temperature by applying this principle, as previously stated.

If all portions of the piece reach the critical range at the same time, the entire piece will expand and contract uniformly. On the other hand, if the piece is heated rapidly through the critical range, the portions having the smaller thermal capacity or proportionally greater surface to absorb heat, will pass this range at an earlier time than the portion having greater thermal capacity. Thus it is evident that parts of the piece will be contracting while other parts are still expanding, which causes stresses to be set up. These often reach such a magnitude that the piece is strained sufficiently to cause distortion.

To demonstrate relative rates of heating near and through the

critical range this series of tests was made on a block of high carbon tool steel. The sample was typical of the blanking dies used for punching motor laminations. In general it may be described as a flat disk 6 inches in diameter and 2 inches thick with teeth cut radially about the periphery. Each tooth was one inch long and $3/8$ inch wide at the smallest section (see Fig. 1).

For the first set of curves, Fig. 2, one thermocouple was located one inch below the surface at the center of the block and the other

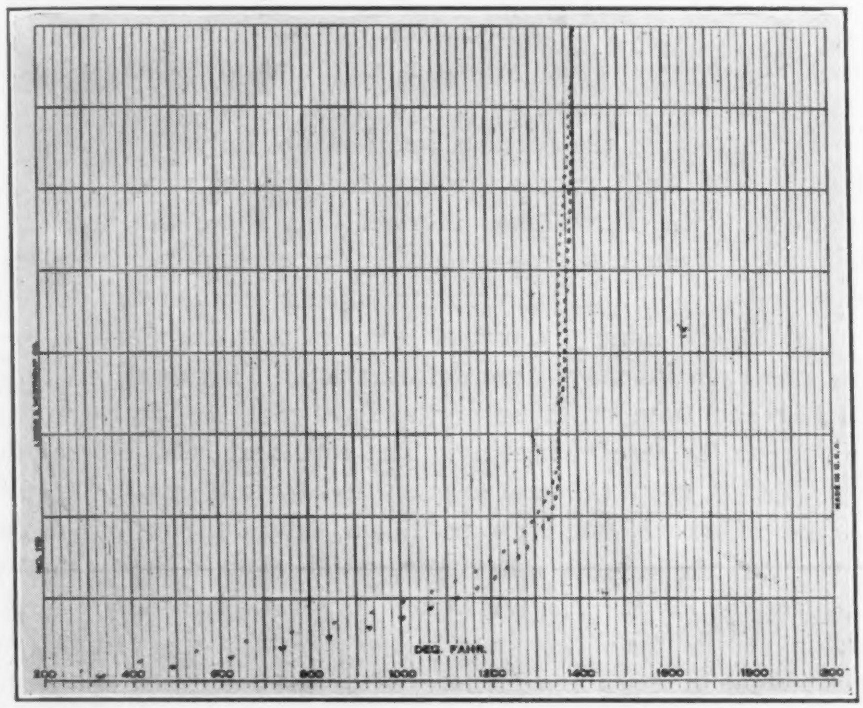


Fig. 2—Heating Curves Obtained from the Tooth and Body of the Blanking Die Shown in Fig. 1. Furnace Temperature Limited to 1400 Degrees Fahr. One Space on the Charts Represents 15 Minutes in Time.

one inch below the surface at the center of a tooth. The thermocouples were carefully installed so that the hot junction in each case was at the bottom of the hole. All thermocouples used for these tests were checked to see that they agreed and also checked against a standard.

To obtain the desired results it was necessary to show simultaneous records of both couples and satisfactory records were obtained with an 2-point dot and dash recorder having a chart speed of four spaces per hour. The interval between impressions was

sufficiently short to give a fairly continuous record. The same piece of steel was used in making all curves so that variations in steel would be eliminated.

With the furnace temperature limited to 1400 degrees Fahr. (Fig. 2) the rate of heating is exceedingly slow, requiring 40 minutes to reach the critical range and 75 minutes more to reach the furnace temperature. The tooth enters the critical range just ahead of the body but due to its lesser thermal capacity passes through the critical range faster than the body. At no time after the critical range is reached does the difference in temperature exceed 20 degrees Fahr. which is slight, considering the relative mass of the two sections.

By increasing the furnace temperature only 50 degrees Fahr. (Fig. 3) the tooth passes through the critical range just as the body enters it. It will be observed that while the body is still undergoing structural change causing contraction, the tooth has become 45 degrees Fahr. hotter, representing considerable expansion.

The elastic limit of the steel is low at this temperature, so that even small strains may cause deformation. This usually results in warping and even cracking of the finished piece, and emphasizes the reasons for careful heating. The 1500 and 1600-degree curves, Figs.4 and 5, show the case exaggerated by still greater gradients.

All of these curves were taken holding constant furnace temperature, in a furnace having large thermal capacity compared to that of the block. The later ones, illustrating the effect of rapid heating at the time the steel passes through the critical, show exactly what happens in a furnace where the maximum temperature is not limited. It is true that the rate of heating in such a furnace can be varied by varying the input to it, but it depends on the skill of the operator to determine the correct input for any particular load. Automatic control takes this important function out of the hands of the operator.

These charts show that as the furnace temperature is increased, the time of heating is shortened decidedly, the time in the critical range is also shortened decidedly, and the difference in temperature between tooth and body at the critical point is increased. One space on the charts represents 15 minutes in time.

The interesting facts brought out in these tests led the writer to consider what takes place in a piece having uniform section,

considering that the temperature of the center of the mass must lag behind the surface since it is heated by conduction from the surface.

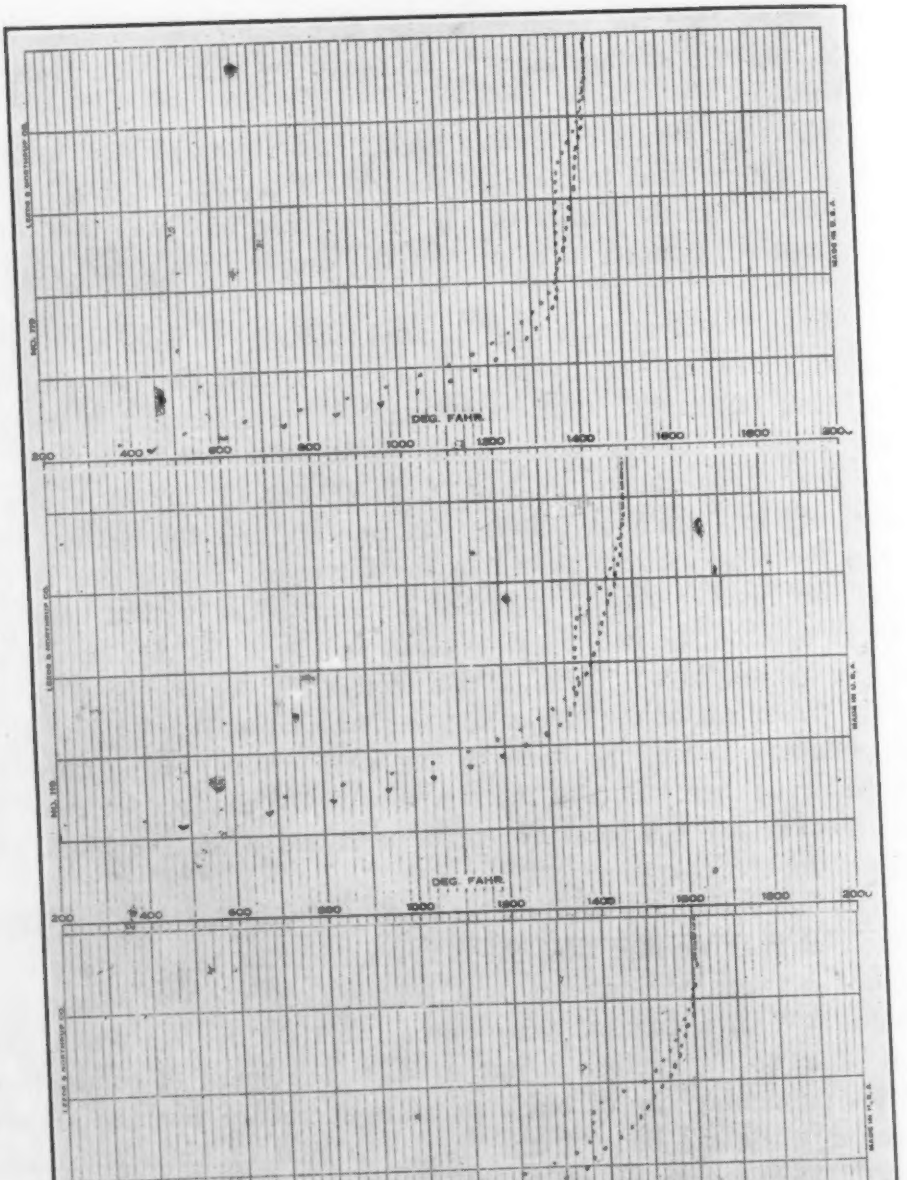
These tests were conducted on the same block of steel by moving the couple used to measure the tooth temperature to a hole ⅛ inch deep near the center of the block. The hole was then filled with insulating material to protect the couple from direct radiant heat.

When the term "surface" is used it should be understood that it is in a stratum slightly below the surface that the temperatures are being taken. This, of course, makes the contrast less marked than would be the case if the actual surface were studied.

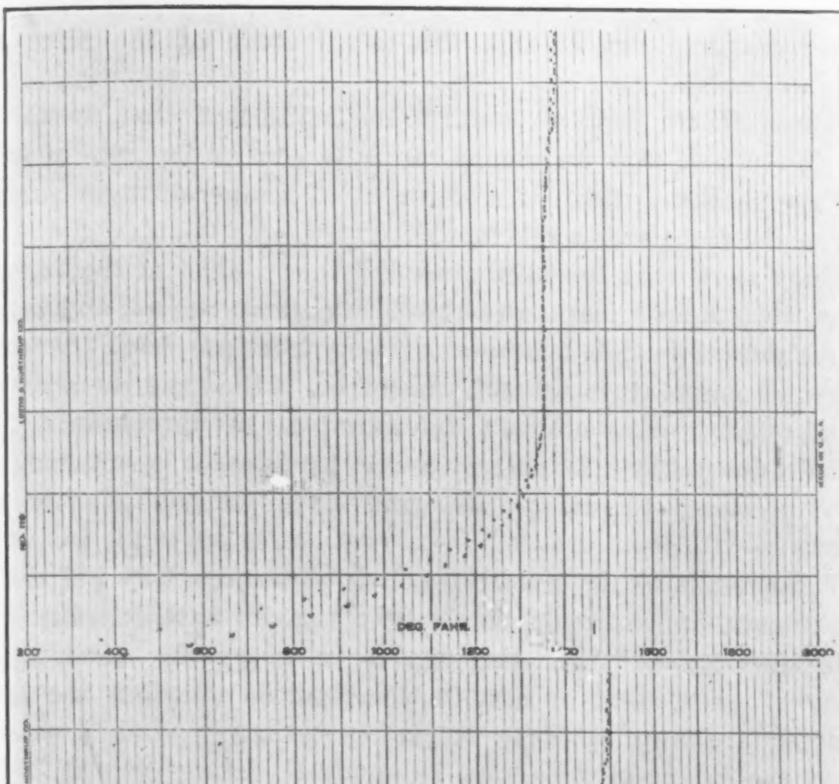
The curve shown in Fig. 6 (1400-degree curve) shows a relatively low gradient between the surface and the center, even when the piece is first placed in the furnace. This is due to the relatively high conductivity of the block. As the critical temperature is reached the gadient is so small that it is not measurable by the means employed. Should this method of heating be followed in the treatment of die blocks and similar shapes, it is evident that little damage would be done to the steel while passing through the critical range. Should the temperature be too low for quenching the furnace temperature could be raised after the block has passed the critical.

By increasing the gradient as in Figs. 7 and 8 (1500 and 1600 degree curves) we find that there is considerable temperature difference between the surface and center as the piece passes the critical. With a furnace temperature of 1500 degrees Fahr. the heat input to the surface is just equal to the speed of conduction in this particular size of block as its temperature remains almost constant while the body is absorbing the heat of transformation. Fig. 8 (1600-degree curve) shows the temperature of the surface constantly rising, the rate being only slightly retarded as the mass passes the critical. In this case there is a marked increase of gradient between the surface and center.

We would thus be led astray if we should depend on a surface couple to indicate the temperature of a block, if the furnace temperature is being held at a value much above the critical temperature. For example, in Fig. 7 (1500-degree curve), if we should quench the steel at 1390 degrees Fahr. as indicated by the surface



Figs. 3, 4 and 5—Fig. 3 is the Upper Set of Curves, Fig. 4 is the Middle Set of Curves and Fig. 5 is the Lower Set of Curves. Fig. 3—Heating Curves Obtained from the Tooth and Body of the Blanking Die with Furnace Temperature Limited to 1450 Degrees Fahr. Fig. 4—Heating Curves Obtained from the Tooth and Body of the Blanking Die with Furnace Temperature Limited to 1500 Degrees Fahr. Fig. 5—Heating Curves Obtained from the Tooth and Body of the Blanking Die with Furnace Temperature Limited to 1600 Degrees Fahr. The Upper Curves of Each Pair Indicate the Temperature of the Body and the Lower Curves the Temperature of the Tooth.



Figs. 6, 7 and 8—Fig. 6 is the Upper Set of Curves, Fig. 7 is the Middle Set of Curves and Fig. 8 is the Lower Set of Curves. Fig. 6—Heating Curves Obtained from the Center and Surface of the Blanking Die when the Furnace Temperature was Limited to 1400 Degrees Fahr. Fig. 7—Heating Curves Obtained from the Center and Surface of the Blanking Die when the Furnace Temperature was Limited to 1500 Degrees Fahr. Fig. 8—Heating Curves Obtained from the Center and Surface of the Blanking Die when the Furnace Temperature was Limited to 1600 Degrees Fahr. The Upper Curves of Each Pair Indicate the Temperature of the Center of the Block and the Lower Curves the Temperature of the Surface.

couple, the body would not yet have passed the critical while the surface couple indicates that the temperature of the piece has begun to rise.

These charts serve to confirm the injunction that we should heat slowly, and that we should carefully control the rate of heating through the critical, if differences of temperature in various parts of the piece are to be avoided.

They show that the minimum differences exist if the furnace temperature is held just above the critical temperature, and this is without doubt the ideal method of heat treating, from the point of view of temperature control. However, if the time required for heating under these conditions, for example 115 minutes in Fig. 2, (1400-degree curve) is excessive for production operations,—it will be necessary to increase the gradient in order to shorten the time.

The amount of the gradient will be determined by individual requirements, but it should be observed that an automatically controlled furnace provides the means necessary for satisfactory heating of tools, dies, or other special parts, and that the same principles are applicable to larger operations. With such apparatus the extent of departure from ideal heating rates is in the hands of the metallurgist.

INCLUSIONS IN IRON

*A Photomicrographic Study**

BY C. R. WOHRMAN

CHAPTER IV

OXIDE-SULPHIDE INCLUSIONS

WE FOUND that pure iron oxide and pure iron sulphide inclusions can exist only in pure iron, and that in general, in the presence of other metallic elements, oxides, resp. sulphides, of these elements will form, and associate with the oxides, resp. sulphides, of iron in a manner governed by the chemical relationships existing between the compounds involved.

Next the question arises what will happen when oxides and sulphides both are present in the melt, as is, in fact, the case in actual iron and steel-making practice. Will the oxides react with the sulphides as they do, for example, in reverberatory copper smelting, and eliminate each other thereby,

$$FeS + 2FeO = 3Fe + SO_2$$

or they will associate peacefully, in a manner analogous to that of oxides among themselves or sulphides among themselves?

1. *The Literature on Oxide-Sulphide Inclusions*

The literature on oxide-sulphide inclusions is exceedingly meager. Le Chatelier and Ziegler (16) were, it appears, the first to discover, in (1902), the existence of a eutectic between iron oxide and iron sulphide. Examining with the microscope artificially prepared iron sulphide, they noted that "between the yellow grains, and frequently around the grains of iron, a substance is found made up of very fine plates having the characteristic appearance of eutectic alloys or of pearlite. One of the components of this eutectic is the yellow sulphide, while the other is a gray

*From a thesis by C. R. Wohrman submitted to Harvard University in partial fulfillment of the requirements for the degree of Doctor of Science in Metallurgy. The experiments were conducted in Professor Sauveur's laboratory. The paper will be divided into five chapters. Chapters I and II appear in July, and Chapter III in the August, 1928, issues of TRANSACTIONS. Manuscript received January 4, 1928.

substance whose color recalls the appearance of slag frequently found in iron and steel."

Later writers when mentioning the iron oxide—iron sulphide eutectic refer frequently to the paper of Treitschke and Tammann (23). This, however, contains merely a note calling attention to the findings of Le Chatelier and Ziegler.

Matveieff (54), in 1920, extended his studies of artificial inclusions to the case of mixed oxide-sulphides. He found that there resulted, in general, three constituents:—a mixed sulphide (with some dissolved oxide), a mixed oxide (with some dissolved sulphide), and a eutectic of the two.

In the chemical literature there exists numerous papers on oxide-sulphide relationships; most of them deal only with reactions at relatively low temperatures. Of some interest is a paper by D. L. Hammick (55) describing the action of SO_2 on FeO and on MnO at elevated temperatures. Textbooks on metallography disregard the oxide-sulphide inclusion relationships entirely.

2. *Experimental Material*

A systematic and thorough study of the more common oxide-sulphide inclusions would imply, first of all, a study of the equilibrium relations of the two fundamental systems:

(1) Fe-FeO-FeS
(2) Mn-MnO-MnS

This was not attempted by the author. His aim was rather to gather such general information about sulphide-oxide inclusions as could conveniently be obtained from photomicrographic studies of suitable melts, and to observe to what extent sulphur elimination was assisted by the presence of oxygen.

Two melts only were prepared; the first to show the relationships between iron oxide and iron sulphide in the absence of foreign elements, notably manganese; the second, to show these relations in the presence of manganese.

Melt SO-1

Charge: Sulphide melt S-2 .... 63.0 grams
Fe_2O_3 .... 2.0 grams
Melted in air; all the oxide charged into a closed container.

Melt SO-2

Charge: Sulphide melt S-7 .... 22.65 grams
Mixed $Fe_2O_3 + Mn_2O_3$ ......about 1.5 grams
Melted in air; the oxide charged in the form of pellets dropped in the melt after fusion of the latter.

Known FeS and FeS-MnS-bearing melts were used as a base to which oxide was added. A comparison of the structures with and without oxide of alloys containing the same (or nearly the same) amount of sulphur was thus made possible. Additional material for the study of oxide-sulphide relationships was provided by the heat treated[28] portions of the sulphide melts S-1 and S-6, which will be referred to as S-1Q, S-1A, S-6Q and S-6A, the letters Q and A standing for "quenched" and "annealed" respectively.

S-1Q Bottom part of the longitudinally cut half of S-1 (See Fig. 50). Annealed for 1 hour at 1760 degrees Fahr. (960 degrees Cent.), heated to 1815 degrees Fahr. (990 degrees Cent.) and quenched in ice-brine.

S-1A Top part of the longitudinally cut half of S-1 (See Fig. 50). Annealed for 2 hours at 1760 degrees Fahr. (960 degrees Cent.) and slowly cooled in the furnace.

S-6Q Middle portion of the longitudinally cut half of S-6. Annealed for 2 hours at 1795 degrees Fahr. (980 degrees Cent.), heated to 1830 degrees Fahr. (1000 degrees Cent.) and quenched in ice-brine.

S-6A The other half of the middle portion of S-6. Treated as S-6Q and reannealed by heating slowly to 1780 degrees Fahr. (970 degrees Cent.) and cooling with the furnace.

3. *Oxide-Sulphide Relationships in Pure Iron*

Pure Iron-Oxide-Sulphide Melt (SO-1). This melt, as just pointed out, was prepared by remelting the sulphide melt S-2 with iron oxide.

General Description of the Inclusions. The inclusions in S-2

[28]Heat treatment was conducted in an ordinary Hoskins annealing furnace and implied the usual amount of surface oxidation.

are shown in Fig. 46, those in SO-1 in Fig. 87. The inclusions in SO-1 appear to be somewhat larger than those of S-2 and, also, decidedly darker. Upon superficial examination one would be tempted to describe them as gray, although, on closer study, they are seen to exhibit a distinctly yellowish tint. At higher magnifications ($\times$ 500) the duplex structure of the larger inclusions, and the presence of a host of minute inclusions, (0.002 millimeters in diameter and smaller), becomes apparent.

Details of the Inclusions. The details of the inclusions (depicted in Figs. 88-92, 93-96) are revealed only at the highest magnifications. Such magnifications show that practically all inclusions are made up of two constituents which are generally associated in a manner typical for a eutectic. One of these constituents is of a yellowish color suggestive of FeS, the other of a gray color suggestive of FeO.

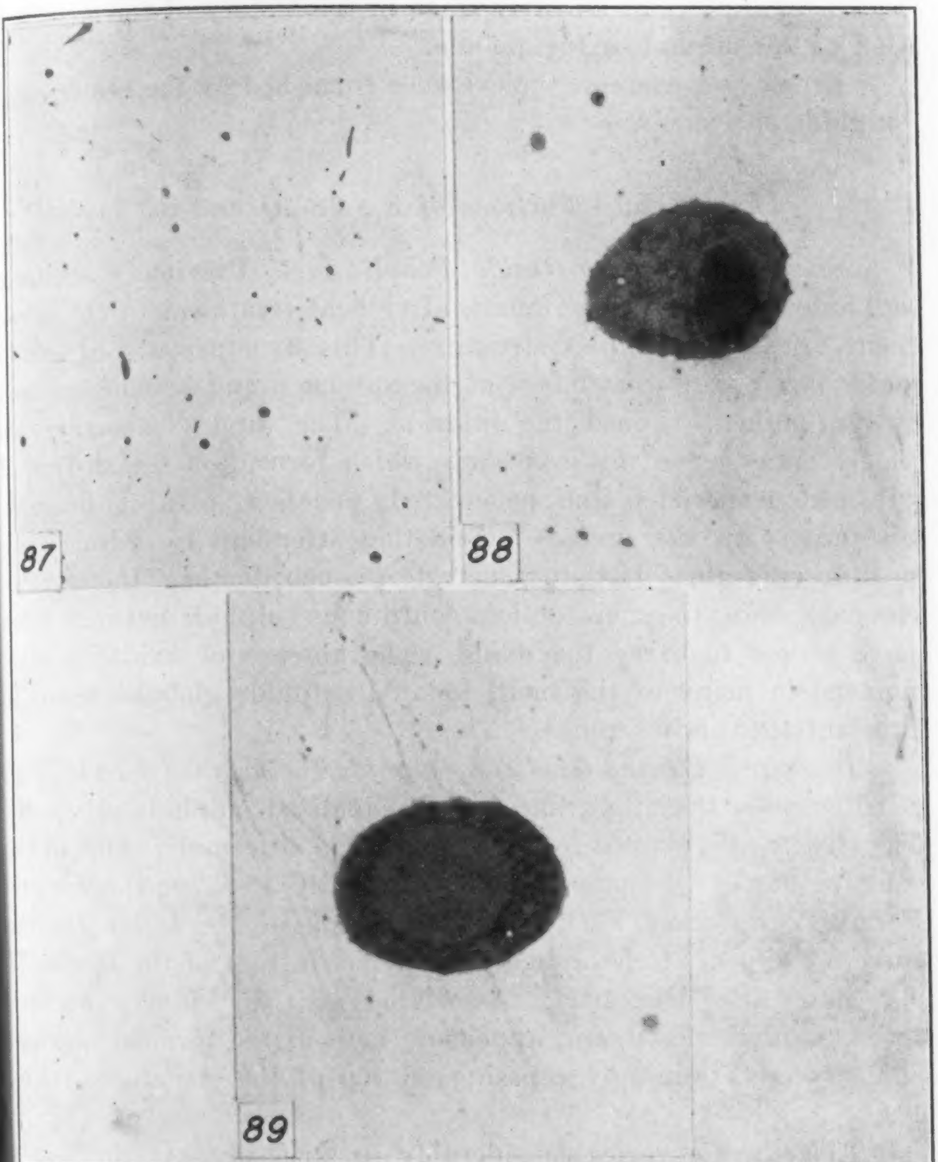
Figs. 88 and 89 are typical for the majority of the inclusions. We have here a well defined (although fine) eutectic surrounding the excess constituent which is either the oxide (Fig. 88), or the sulphide (Fig. 89). Occasionally the excess constituent is seen to be preserved in its original (?) dendritic form as is, for example, the excess oxide of Fig. 90 (large inclusion).

A unique case where all of the oxide appears in the form of dendrites embedded in a sulphide (or submicroscopic sulphide-oxide) matrix is illustrated by Fig 91.

Another unusual case is shown in Fig. 92. Here the oxide and the submicroscopic sulphide-oxide eutectic are arranged in a Widmanstätten pattern which would indicate separation of the oxide from a solid solution.

Considerably more frequent are the structures illustrated in Figs. 93-96. Here, for the first time, we meet a third constituent which appears in symmetrically arranged plate-like forms of a dark gray color. This constituent comes in as an independent unit which, seemingly, does not interfere with the usual FeO-FeS relationship. The early formation of this constituent is suggested by the manner in which the plates, at times, project beyond the general boundary of the inclusions.

What is the nature of this third constituent? It surely is not a sulphide of iron judging by its color; nor is it likely that it is a solid solution of sulphide and oxide, because a solid solution



Inclusions in the Pure Iron-Oxide-Sulphide Melt SO-1 Fig. 87—A Group Typical for the Specimen. × 100. Fig. 88—Excess Oxide Surrounded by the FeS-FeO Eutectic. × 2500. Fig. 89—Excess Sulphide Surrounded by the FeS-FeO Eutectic. × 2500.

would not crystallize earlier than the pure components. There remains one possibility: the constituent is an oxide of iron different from FeO. May it not be the magnetic oxide Fe_3O_4? This oxide is known to occur in solution in FeO. It also appears reasonable to expect that its solubility in FeO which is contaminated by FeS is lower than in pure FeO, and that, therefore, precipitation of

Fe_3O_4 takes place at an early stage in the history of the solidification of the sulphide-oxide globule.

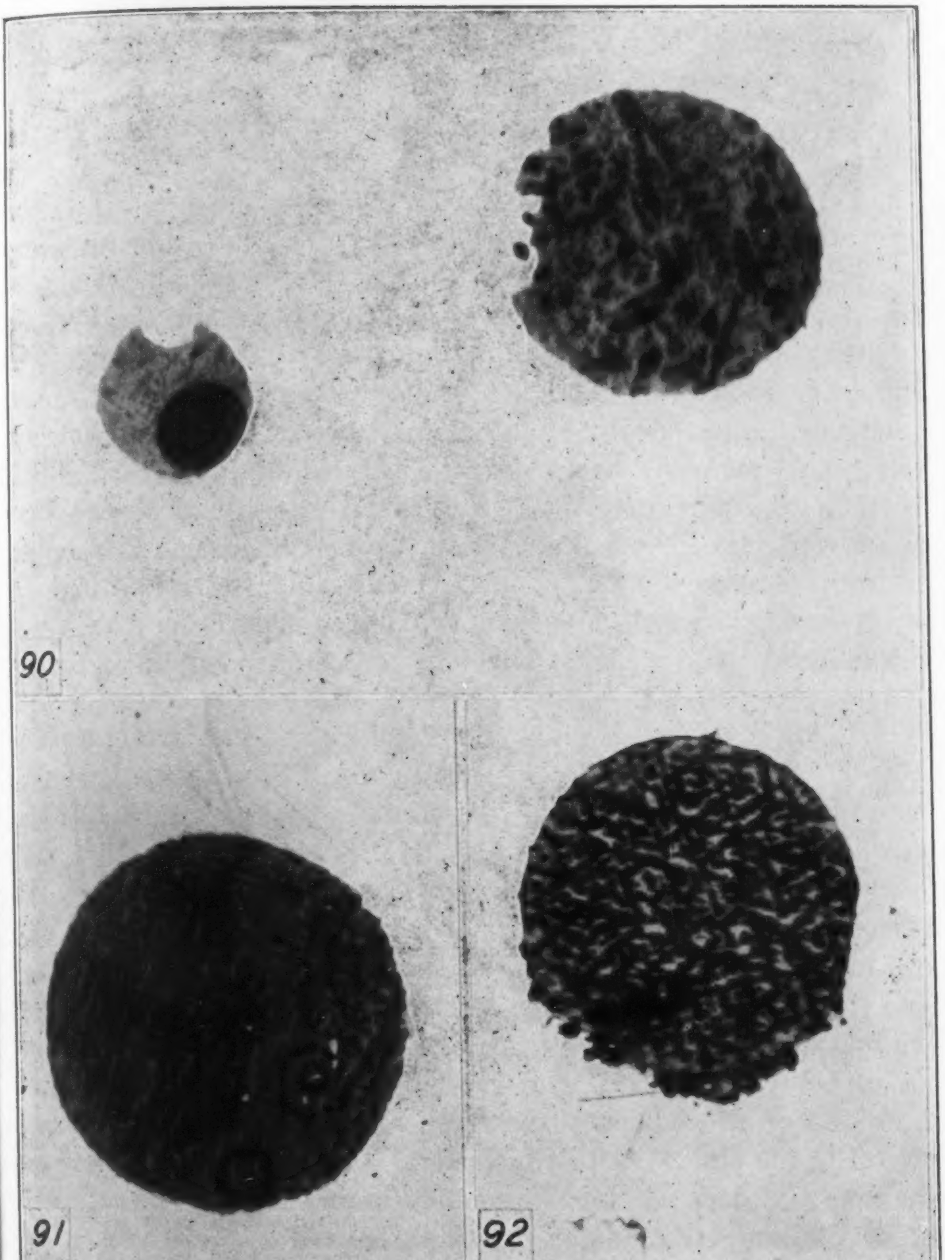
Let us now examine the evidence furnished by the heat treated sulphide specimens.

The Oxidized Portions of S-1 (S-1Q and S-1A)

The Mechanism of Oxide Penetration. Previously uniform sulphide inclusions were found, after heat treatment of the specimens to exhibit a duplex structure. This structure was especially pronounced near the surface of the specimen and became less and less prominent toward the interior. The duplex structure obviously, was caused by iron oxide which formed on the surface of the heated specimen and penetrated, somehow, to a considerable distance below the surface. Oxidation attendant to ordinary annealing operations fails to penetrate to such depths. In the present case, then, the more or less continuous sulphide network must have served to carry the oxide. The absence of oxidation phenomena in many of the small isolated sulphide globules seems to substantiate this inference.

Description of the Oxidized Sulphide Inclusions (S-1A). Fig. 98 illustrates the appearance of the oxidized sulphide cell walls. The structure is typical for a eutectic (or a eutectoid). One of the constituents of the eutectic is, undoubtedly FeS (or the eutectic Fe-FeS), the other FeO. The proportion of the latter (in the eutectic) appears to be, roughly, 30 per cent, that of the former 70 per cent. (See Fig. 104). Associated with the eutectic we find, again, a third constituent, appearing here in the form of idiomorphic crystals, seemingly reposing on top of the structure. (Fig. 98).

The eutectic varies considerably in structure. At times it is exceedingly fine, and at times so coarse as to suggest a complete divorce of the constituents. An interesting instance of this is pictured in Fig. 99. The eutectic structure of the middle inclusion is so fine that it can hardly be perceived at the magnification used, while that of the neighboring inclusions, removed only a few hundredths of a millimeter from the first inclusions, is distinctly coarse. The difference becomes still more apparent when higher magnifications are used. Compare, for example, Fig. 100 and 102, which depict, at $\times$ 2500, the middle inclusion of Fig. 99



Inclusions in the Pure Iron-Oxide-Sulphide Melt SO-1. Fig. 90—An Example of Excess Oxide Occurring in Dendritic Form. × 2500. Fig. 91—An Unusual Inclusion. Oxide Dendrites in a Sulphide Matrix. × 2500. Fig. 92—Oxide and Sulphide in a Widmanstätten Pattern. × 2500.

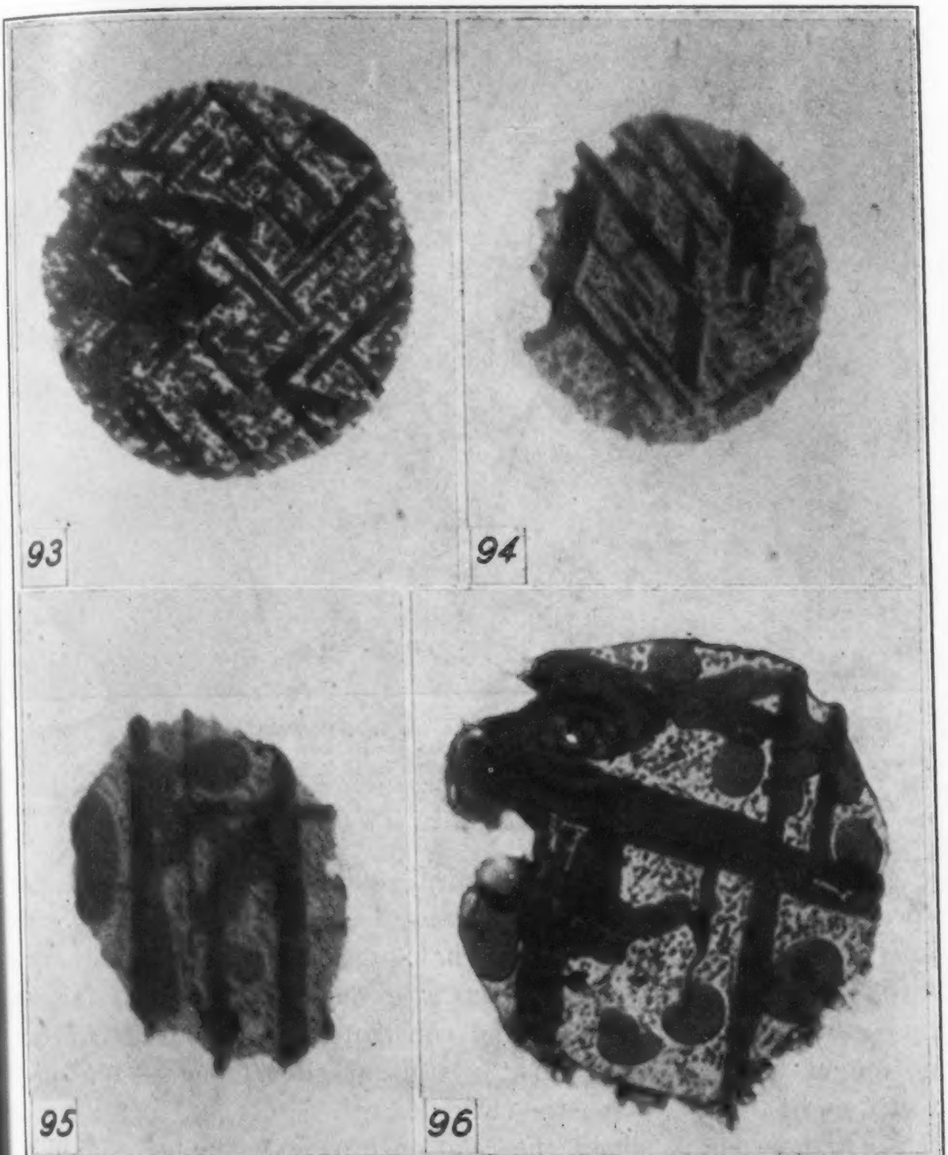
and an inclusion immediately adjoining it. In one case we have a very fine eutectic, in the other no eutectic at all,—yet, in both cases, the same proportions of FeO and FeS seem to be present.

In both cases we observe also the presence of constituents other than FeS and FeO. In Fig. 100 a "mid-rib" and a few "side-ribs" of the dark oxide are revealed, while Fig. 102 exhibits the same constituent in the form of a perfect crystal suggesting orthorombic (or perhaps octahedral) symmetry.

In Fig. 102, furthermore, a fourth constituent is visible, intermediate in color between FeO and the dark crystal. It appears as an island faintly outlined in the midst of the main FeO area. The differences in shade between this constituent and the FeO are so delicate that they are visible only with difficulty even at the highest magnifications used. Once discovered, however, this fourth constituent could easily be found in many inclusions in which it had been previously overlooked. Figs. 101 and 105 serve to illustrate its characteristics. It was found to occur always in close association with FeO, and always in the form of islands surrounded by FeO. The dark crystals, on the other hand, are found to have, at times, an existence independent of FeO. A striking example of this is illustrated by Fig. 103, which shows a dark crystal embedded in faint yellow sulphide.

Etching Tests. Further peculiarities in the oxide-sulphide relationships were revealed on etching for 1½ minutes with a 10 per cent alcoholic solution of nitric acid. This treatment did not affect the dark crystals, nor, of course, the yellow sulphide. The intermediate gray constituents were found, however, to have undergone changes. The boundaries between them, originally faint and indistinct, (perhaps due to the smearing of polishing), appear now clear cut and sharp. The gray constituent enveloped by FeO exhibits, further, signs of having been attacked by the etch. (Figs. 106 and 107). Fig. 107 is of especial interest, showing that even the oxide of the eutectic is complex. Note also the large black crystal in the middle of this inclusion. It crosses sulphide and oxide alike and does not seem to modify in any way the structure of either the complex oxide or the sulphide.

The influence of sulphur printing was studied next. Printing for 30 seconds (using a 2 per cent H_2SO_4 solution) had no influence on the sulphides, induced, however, changes in the oxides which were quite analogous to the changes effected by the nitric acid etch. Prolonged printing developed grain boundaries in the sulphide and caused the complete removal of the darker oxide. (Fig. 108).



Figs. 93 and 94—Plates of a Darker Constituent (+FeO) Occurring in Widmanstätten Patterns in the Usual Oxide-Sulphide Matrix. × 2500. Figs. 95 and 96—Inclusions Illustrating the Association of the Dark Oxide with FeO. Note the Manner in Which Some of these Oxide Plates Project Beyond the Main Mass of the Inclusion Causing Reentrant Angles in the Outlines of the Oxide-Sulphide Eutectic. × 2500.

The Quenched Specimen (S-1Q). The quenched specimen was exposed to the oxidizing atmosphere of the annealing furnace for a considerably shorter time than the specimen just discussed. Oxidation, therefore, was less pronounced here, and an excess of sulphide, in the oxidized inclusions, was generally noted.

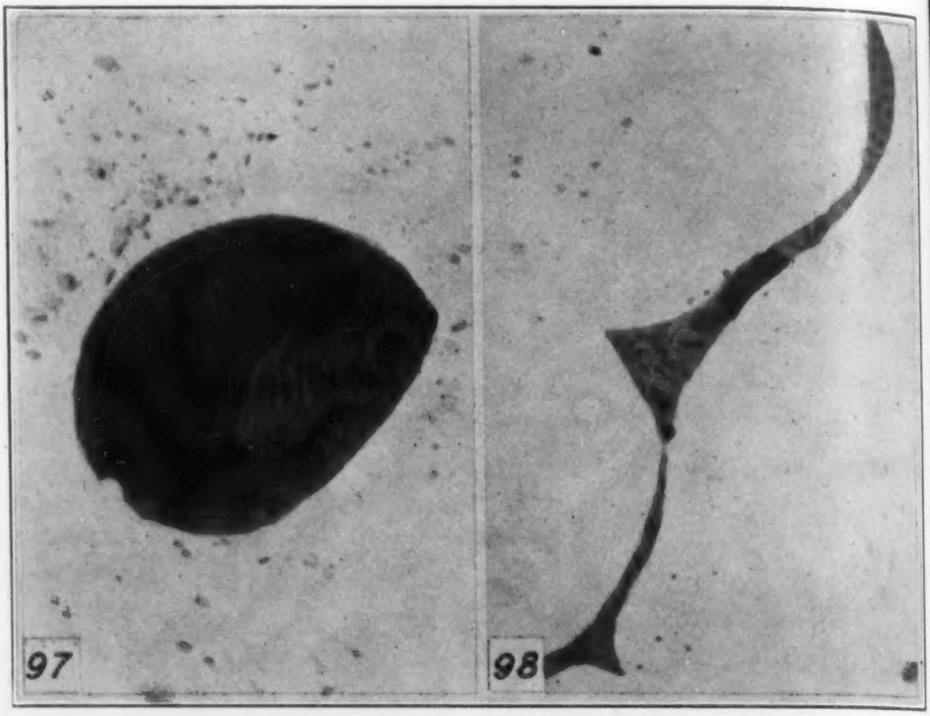


Fig. 97—Another Complex Inclusion. Note the Duplex Structure of the Oxide Mass in the Middle of the Inclusion. The Darker Oxide here is Less Dark than in the Previously Described Inclusions—at the Same Time it Fails to Exhibit a Plate Like Form. Note Also the "Balling Up" of Oxide in the Spot at the Right Side of the Inclusion. A "Deoxidized" Sulphide Rim Surrounds this Oxide Globule. × 2500. Fig. 98—A Typical Sulphide Stringer Converted to a FeS-FeO Eutectic with two Crystals of a Dark Oxide. × 500.

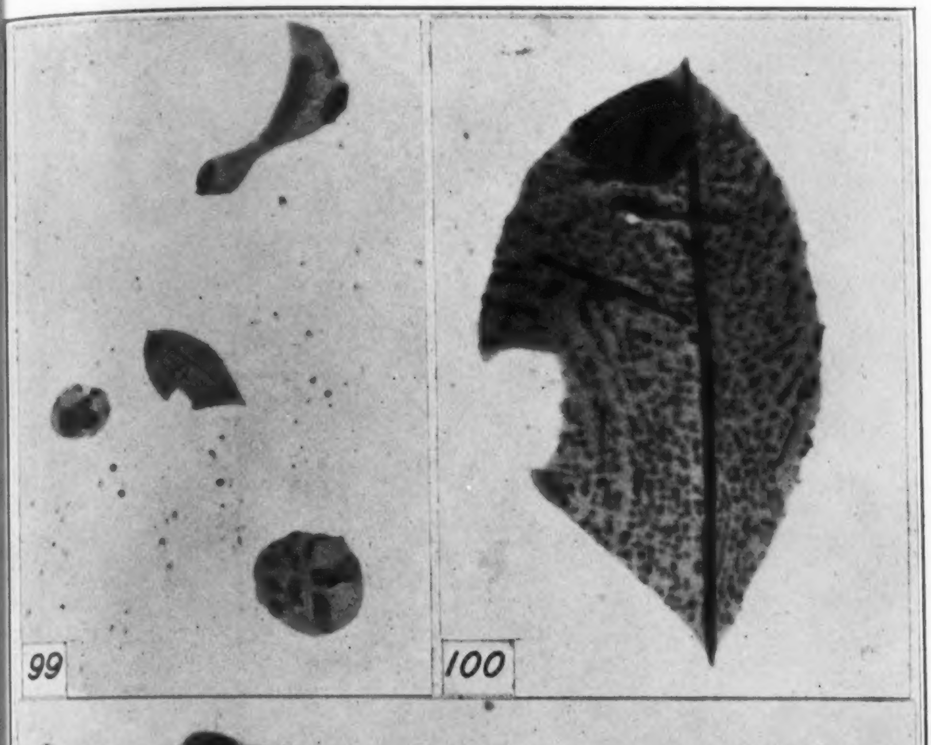
Figs. 109-111 illustrate typical oxidized inclusions of this specimen. The excess sulphide fails, here, to appear in a single area, but assumes a form somewhat suggestive of dendritic crystallization. The eutectic matrix is exceedingly fine—in fact so fine in many instances that the constituents of the eutectic can no longer be seen. The dark crystals are developed just as perfectly as in the previous case (Fig. 111).

Further details about the relationships in quenched sulphide-oxide inclusions (primarily applicable to the case of pure iron oxide and iron sulphide) will be learned from a study of specimen S-6Q.

4. *Oxide-Sulphide Relationships in the Presence of Manganese*

The Quenched Oxide-Sulphide of S-6Q

Description of the Inclusions. Fig. 112 shows a sulphide stringer at the very surface of the specimen, which experienced

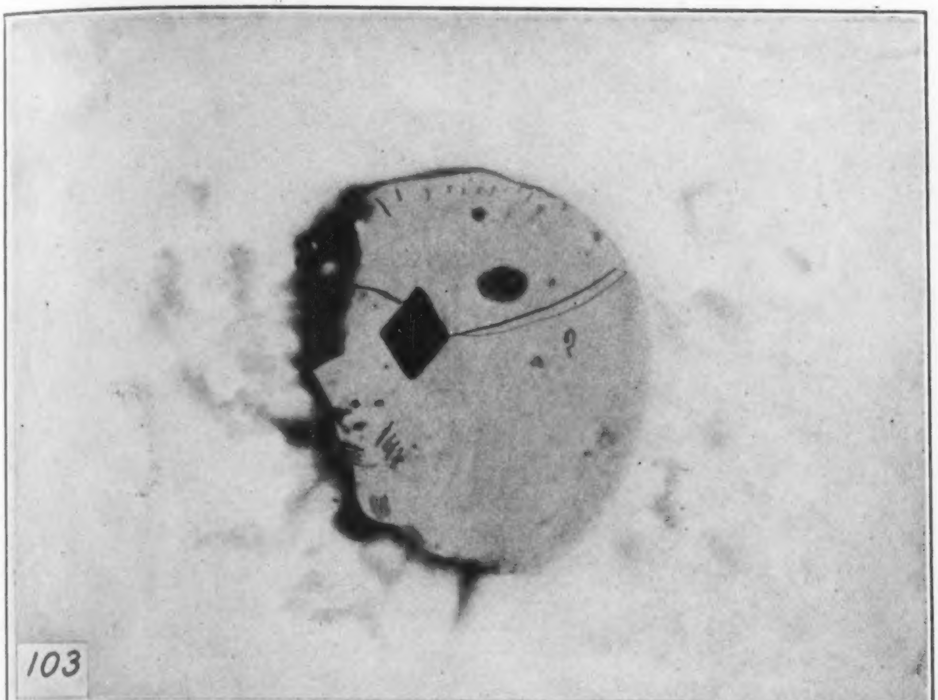


Oxidized Iron Sulphide Inclusions in S-1A. Fig. 99—The Oxide-Sulphide Eutectic Varies Greatly in Fineness in Different, Often Neighboring, Inclusions. × 500. Fig. 100—The Middle Inclusion of Fig. 99 Shows an Especially Fine Eutectic. Note also the Midrib (and Side Ribs) of a Dark Oxide Which Influences the Shape of the Inclusion. × 2500. Fig. 101—The Right Inclusion Shows a Complete Separation of Constituents of Which There are Four: The Crystal, the Dark Oxide, the Normal Oxide and the Pale Yellow Sulphide. × 2500.

Oxidized Iron Sulphide Inclusions in S-1A. Fig. 102—The Upper Right Inclusion of Fig. 99. Note the Crystal Surrounded by Pure FeS; Also the Dark Oxide within a Patch of Normal Oxide. Complete Separation of All Constituents is Shown. × 2500.

both thorough oxidation and drastic quenching. Apart from the presence of numerous dark crystals the sulphide appears homogeneous throughout.

There was undoubtedly enough oxide available for the formation of the FeO-FeS eutectic. Its absence, combined with the distinctive mixed yellow gray color of the sulphide, shows that the quenching either prevented separation of the constitutents of the



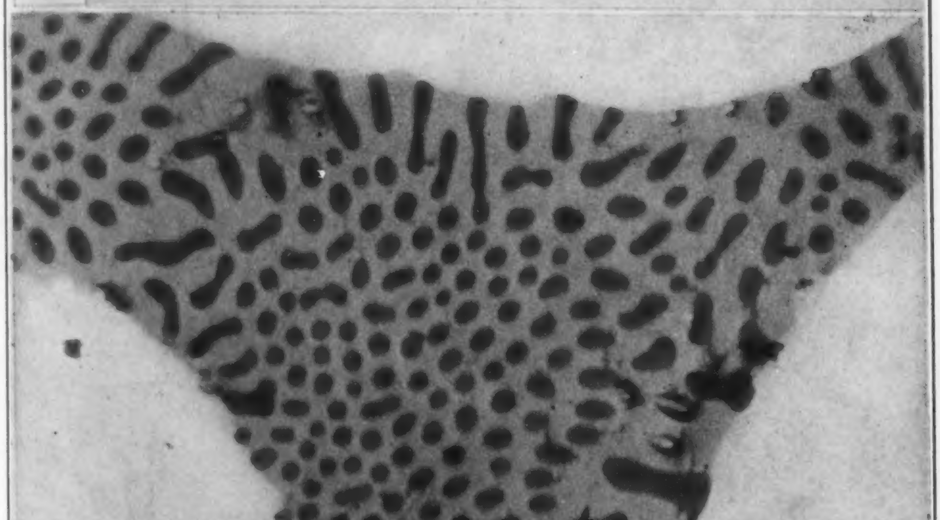


Fig. 103—A Yellow FeS Inclusion Carrying a Perfectly Developed Dark Crystal. × 2500.
Fig. 104—Inclusion of FeS-FeO Eutectic. The Proportion of Oxide and Sulphide Appears Constant. × 2500.

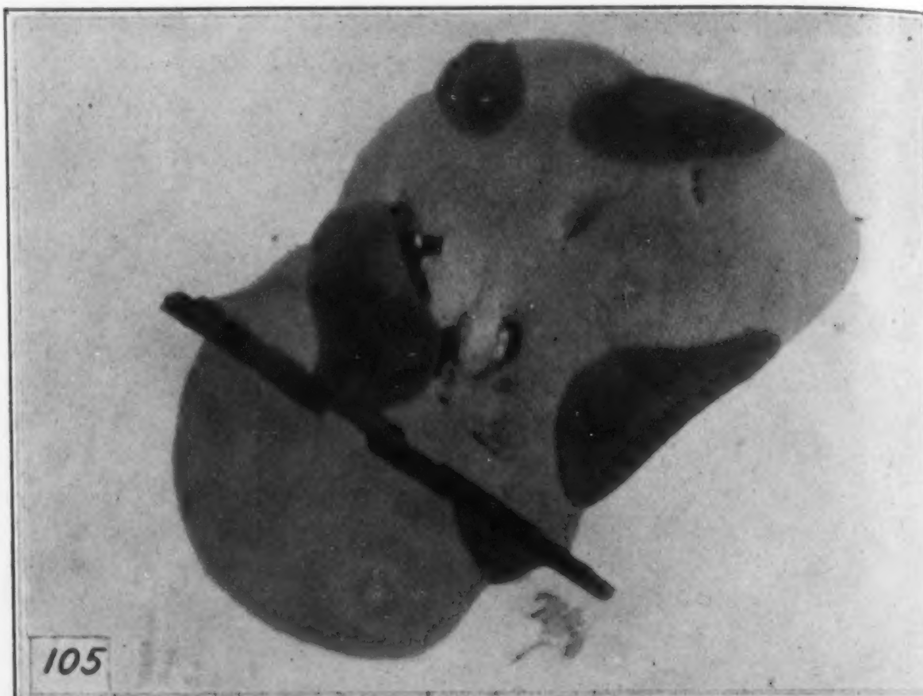


Fig. 105—Three Different Gray Oxides (or Oxide-Sulphides) in a Pure FeS Matrix. × 2500. Fig. 106—Same as Fig. 105 After Etching for 1½ Minutes in 10 Per Cent Alcoholic Nitric Acid. × 2500.

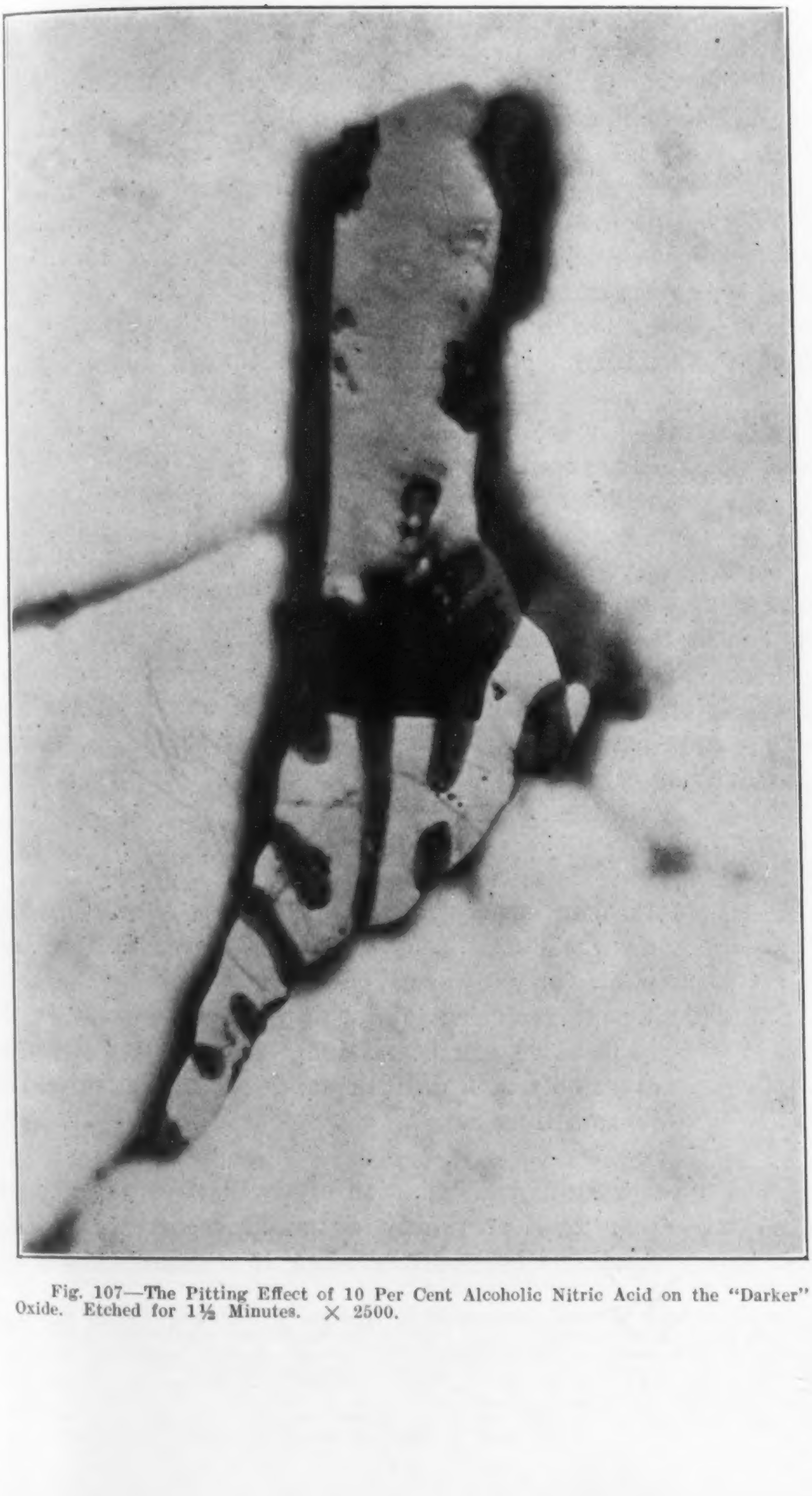


Fig. 107—The Pitting Effect of 10 Per Cent Alcoholic Nitric Acid on the "Darker" Oxide. Etched for 1½ Minutes. × 2500.

eutectic altogether, or else prevented the separation of constituents sufficiently large to be visible. (Fig. 114).

Alongside of the inclusion just described (Fig. 112) a group of rounded sulphide inclusions rich in MnS is seen. No change, (from the original), in color nor form is discernible in these inclusions. They are either immune to oxide attack at 1795 degrees Fahr. (980 degrees Cent.), or, being discontinuous, they were not reached by the oxide. At any rate, the appearance of these inclusions is uniform throughout the specimen.[29]

This is not true of the inclusions rich in FeS. As we proceed from the oxidized rim of the specimen toward the interior a duplex structure becomes apparent in these inclusions. Dendritic forms of the gray color of FeO, or, more often, of the pure yellowish of FeS, are seen to appear here and there in the uniformly colored yellowish gray matrix of the inclusions. (Figs. 116 and 117). It appears that these dendrites represent excess oxide, resp. sulphide, the precipitation of which could not be entirely suppressed by quenching which was less drastic than that effected at the rim of the specimen. Higher magnifications support this inference. Fig. 119, for example, shows that wherever separation of excess oxide has taken place, the eutectic nature of the matrix becomes apparent also. This is equally true for the case of excess sulphide, although, here, the eutectic of the ground mass is visible less clearly (Fig. 120).

In general, we are justified in concluding:

(1) that we have, at 1795-1830 degrees Fahr. (980-1000 degrees Cent.), a uniform solution of oxide in sulphide (or vice versa),

(2) that this solution (although preserved on very drastic quenching) can be retained at atmospheric temperature only with difficulty and tends to break up into its constituents.

The appearance and distribution of the dark crystals differs in no way from their previously described occurrences. They must have formed at a temperature below 1000 degrees Cent. and

[29]An exceptional inclusion consisting of an aggregate of two "grays"—both typical for MnS rich sulphides—is pictured in Fig. 118. It was found well toward the middle of the specimen and illustrates, in all probability, an unusual sulphide relationship caused by quenching. (No traces of oxide could be located in inclusions nearby.)

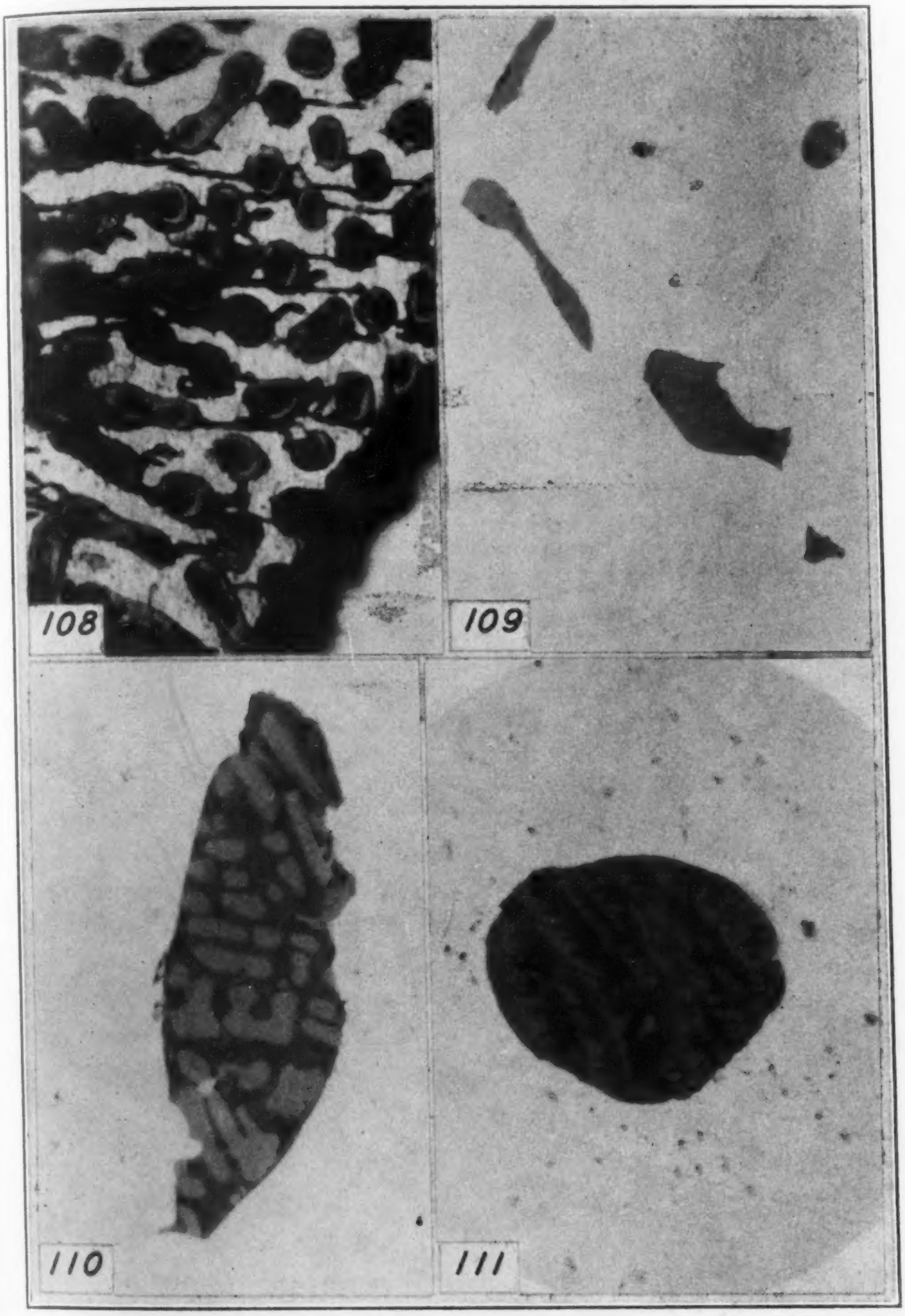
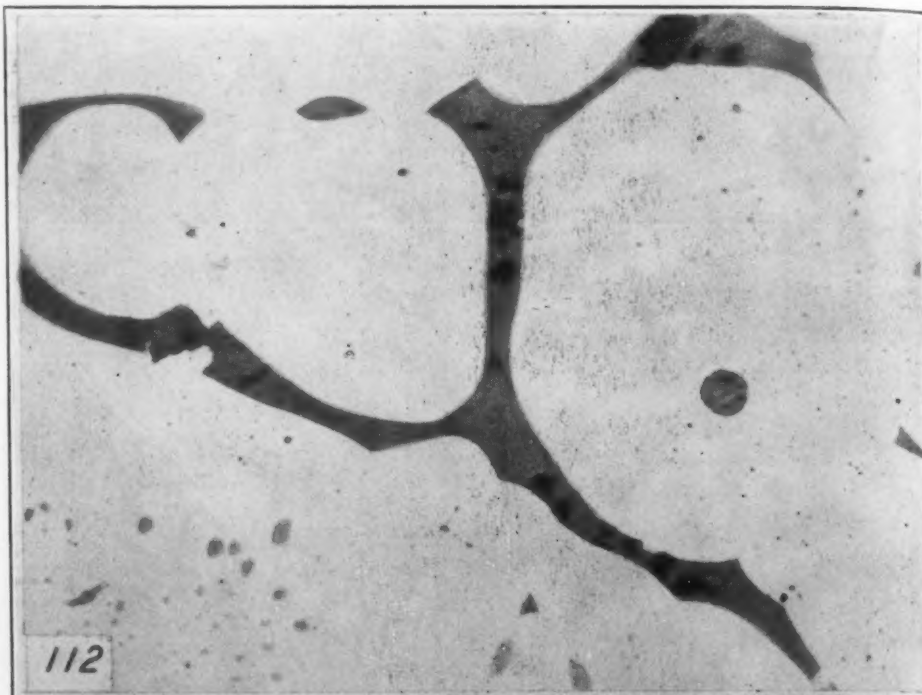
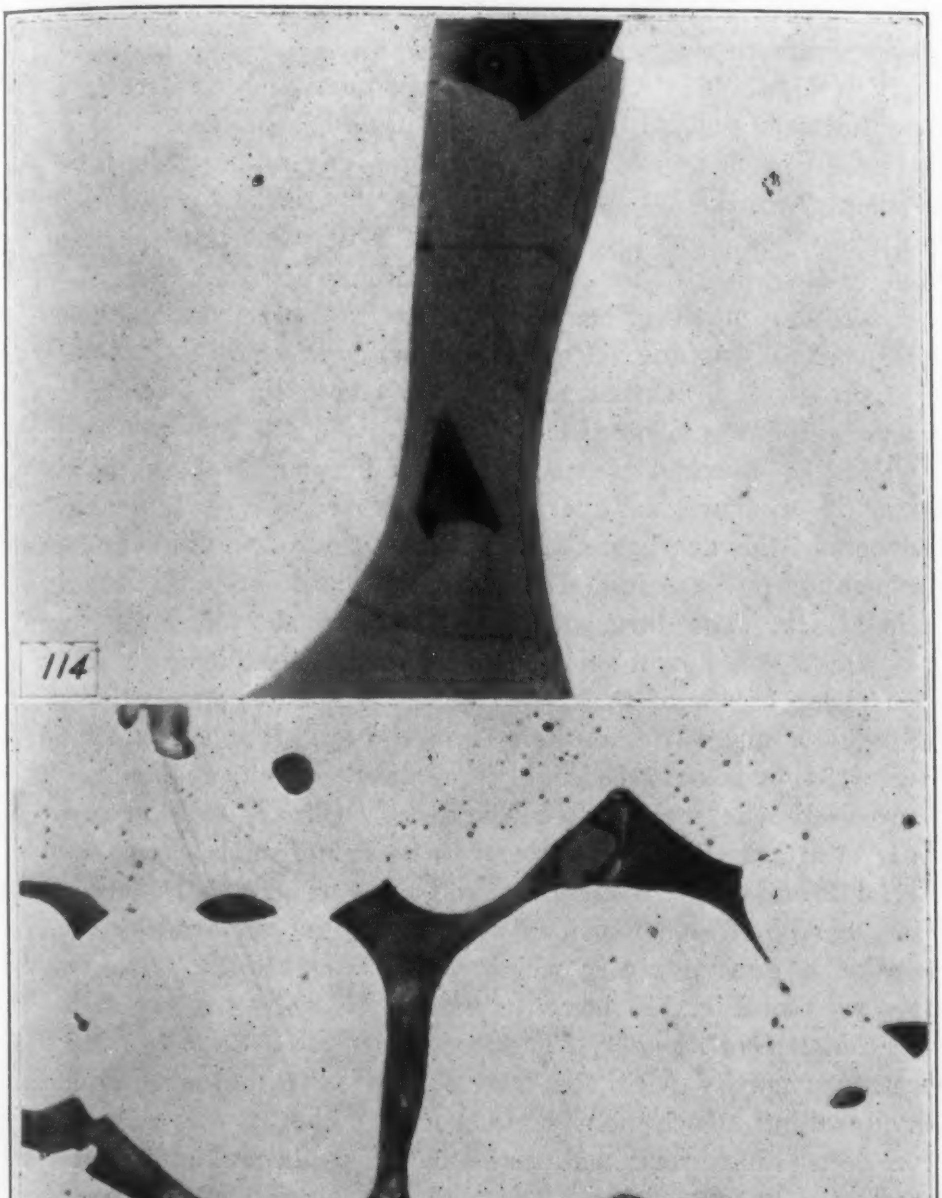


Fig. 108—Etching Effects of Sulphur Printing for 3 Minutes. Note the Development of Grain Boundaries in the FeS, the Dissolution of the Darker Oxide, and the Survival of the Normal Oxide Rims. × 2500. Quenched Oxidized Inclusions in S-1Q. Fig. 109—A Fair Duplex Structure is Discernible in Some Inclusions at × 500. Fig. 110—The Excess Sulphide has not had Time to Coagulate. Note the Fineness of the Eutectic of the Ground Mass. × 2500. Fig. 111—The Eutectic of the Ground Mass is not Resolved. Note the Presence of an Oxide (?) Crystal (Which was Pitted Out) in this Inclusion Which Otherwise Suggests the Presence of Excess Sulphide. × 2500.



Quenched Oxidized Inclusions in S-6Q. Fig. 112—Oxidized Sulphide Cell Wall Near the Surface of the Specimen, Drastically Quenched. Note the Absence of a Visible Eutectic in this Yellowish Gray Stringer, Also the Presence of Numerous Crystals. The Small FeS-MnS Dots (Upper Left Corner) Appear Unaffected by the Heat Treatment. × 500. Fig. 113—Same as Fig. 112 After 20 Seconds Sulphur Printing 2 Per Cent Sulphuric Acid. The Crystals are Preserved. Against the Dark Background they Appear now Bright. × 500.



Quenched Oxidized Inclusions in S-6Q. Fig. 114—Middle Portion of Fig. 112. High Powers Reveal a Suggestion of Heterogeneity in the Stringer. × 2500. Fig. 115—Same as Fig. 113 After Prolonged Sulphur Printing. The Crystal Still Present Shows no Signs of Having been Attacked. × 2500.

must have essentially completed their outlines before the quenching operation.

Etching Effects. The behavior under etching treatment of the uniform yellowish gray oxide-sulphide (solution?) is of interest. Chromic acid failed to induce any changes in this constituent; attacked, however, some of the darker manganese-rich sulphide inclusions, the remainder of which was taken care of, as was to be expected, by 20 seconds sulphur printing.

Sulphur printing had also a disastrous effect on the yellowish gray mixed sulphide. Fig. 113 shows how readily this material was destroyed by a treatment that left both the excess oxide and excess sulphide unchanged.

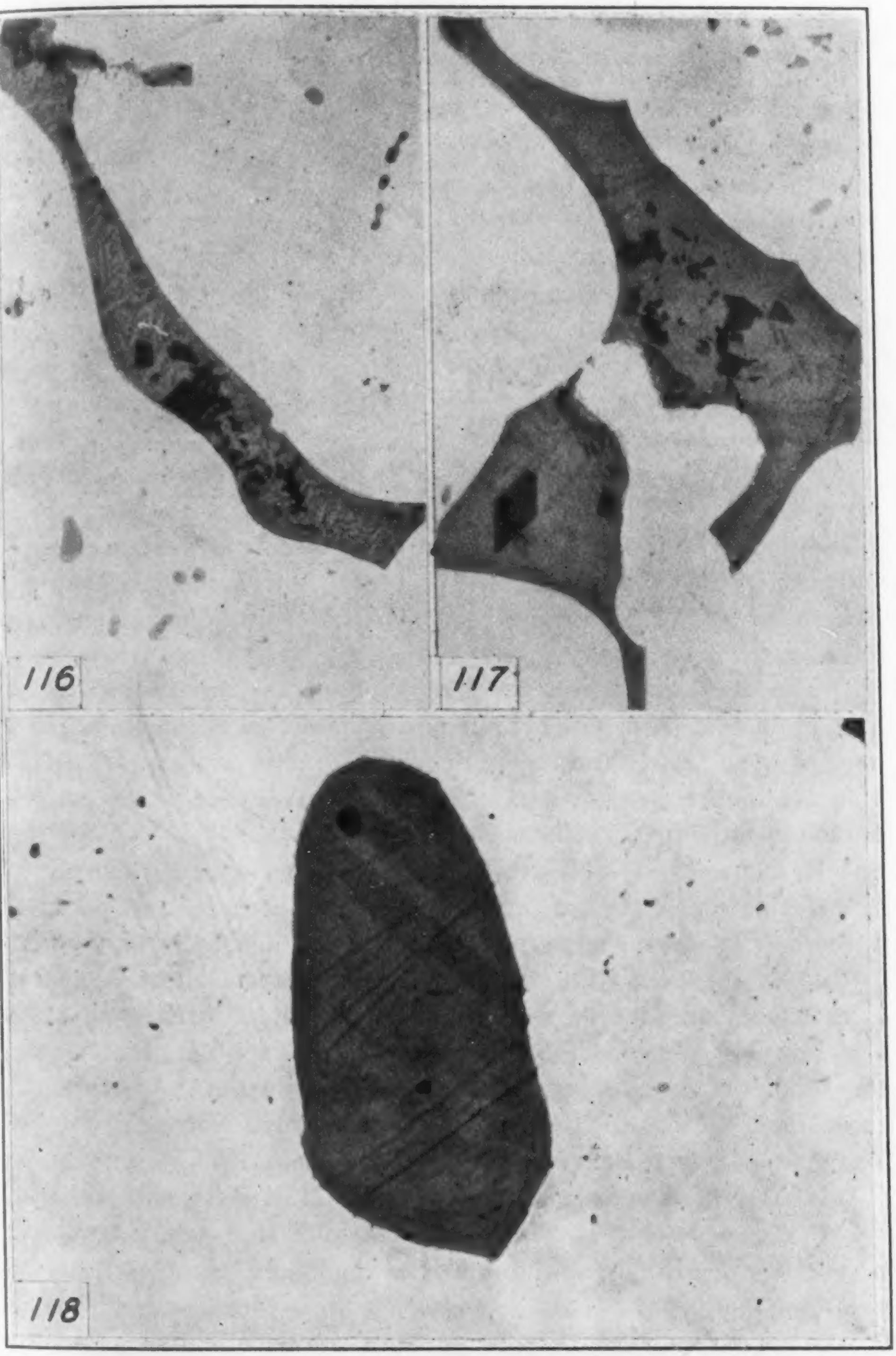
If the attacked constituent is an aggregate of sulphide and oxide its weakness toward acid reagents can be explained by the fineness of this aggregate. If it is a solution of sulphide and oxide we cannot but conclude that such solutions succumb readily to acid attack. The dark constituent of S-1A showed similar weakness; may it not be a solution of sulphide in oxide after all?

The behavior of the dark crystals is another item of interest. If they are magnetite, as their form and association would tend to suggest, they should be highly resistant to acid reagents. This is precisely what we find to be the case. Ordinary sulphur printing fails to attack these crystals as can be seen from a comparison of Fig. 112 and 113. Even prolonged sulphur printing (for 5 minutes) has no effect on such crystals as are not removed by the dissolution of the matrix in which they are embedded. The crystal preserved in Fig. 115 bears witness to this effect.

Concluding Remark. The features of S-6Q described are concerned primarily with the iron oxide-iron sulphide relationship on quenching. Such inclusions as could be identified as rich in MnS were seen to have remained unaffected by oxidation, and essentially unaffected by quenching. The limiting solution of FeS in MnS, which originally was part of the streaks of predominantly yellow sulphide, is now, undoubtedly part of the solid solution, or of the fine aggregate, into which these streaks were converted. The manner in which this limiting FeS-MnS solution reacted toward the oxide cannot be inferred from the present specimen.

The Annealed Oxide-Sulphide of S-6A

Description of the Inclusions. The structures observed in



Quenched Oxidized Inclusions in S-6Q. Sulphides Somewhat Removed from the Edge of the Specimen, Hence Quenched Less Drastically. Note the Crystals and the Dendritic Forms of the Excess FeS. × 500. Fig. 117—As Before, with Dendritic Forms of Excess Oxide. × 500. Fig. 118—An Unusual FeS-MnS Inclusion Toward the Middle of the Specimen. (Unoxidized). It Exhibits Two Different Shades of Gray. × 2500.

the quenched specimen were found to have entirely disappeared after annealing. Instead one finds near the oxidized surface the typical oxide-sulphide eutectic, associated with the various rounded MnS-rich inclusions which show no signs of having been oxidized. The amount of oxide diminishes toward the middle of the specimen until, finally, a region entirely unaffected by oxidation is reached. Here the typical sulphide inclusions described previously are found in precisely the same relationships as before. It was noted, in particular, that the sulphide cell walls were made up, as before, of an aggregate of yellow sulphide and the pale gray limiting solution of FeS in MnS. The appearance of these cell walls after oxidation is depicted in Fig. 121. They are seen to be made up of a eutectic of yellow sulphide and gray oxide.

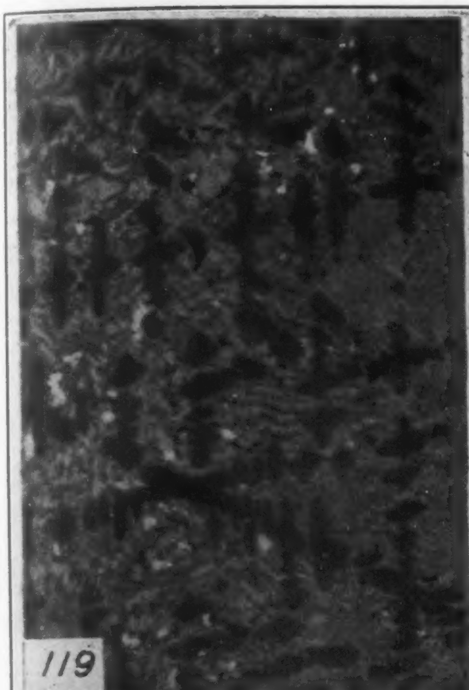
What happened to the pale gray limiting solution of FeS in MnS which, without doubt, was present in these cell walls prior to oxidation? Is the FeS-MnS solution preserved and represented by part of the gray constituent of the eutectic? Or did the manganese leave the sulphur and join the oxide? Or did the manganese leave the inclusion altogether joining the metal?

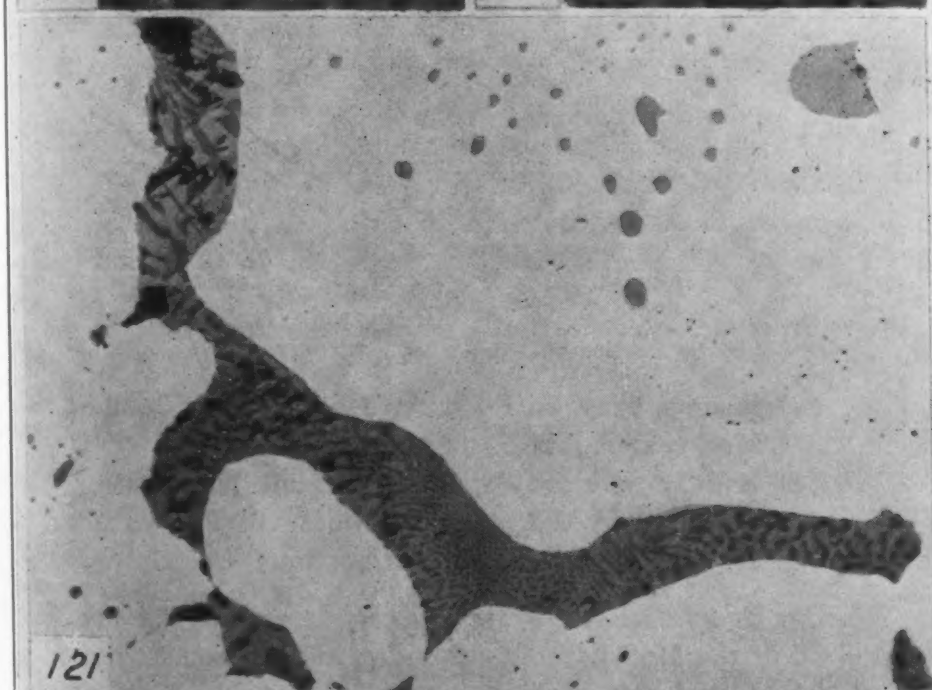
The last suggestion hardly deserves further consideration. The readiness with which manganese combines with sulphur and with oxygen is well known; what could force it to leave these combinations and join the metal? The manganese that was present in the inclusion must, then, be still there.

It is, perhaps, difficult to differentiate between the gray of this sulphide and the gray of the oxide in the eutectic. Still, the difference in shade between the oxide and the MnS-rich rounded inclusions nearby is quite distinct, as is seen from an inspection of Fig. 121. The sulphide appears somewhat lighter than the oxide. The limiting solution of FeS in MnS which is still lighter should, therefore, be distinguishable rather readily from the oxide. A careful search for such lighter specks was made in all of the oxidized inclusions. Only one instance was found where an area of gray, barely lighter than that of the normal oxide, was discernible.

For the general case we must conclude that such manganese as was present in the sulphide cell walls joined, upon partial oxidation of the latter, the oxide portions. This inference is supported by the behavior of these oxide portions toward etching, as will be seen later.

Not all of the oxidized inclusions exhibit the typical eutectic





Quenched Oxidized Inclusions in S-6Q. Fig. 119—Dendritic Forms of Excess Oxide in a Eutectic Matrix. × 2500. Fig. 120—Excess Iron Sulphide in a Eutectic Matrix. × 2500. Oxidized Sulphide Inclusions, Quenched and Annealed in S-6A. Fig. 121—The Typical FeS-FeO Eutectic. Note that the Globular FeS-MnS Inclusions (on the Left) Appear Unchanged. × 500.

just described. In a number of the smaller inclusions a more or less complete separation of all constituents is observed, much like in the case of some of the inclusions of S-1A. Fig. 122 shows a typical inclusion of this type as recorded through a red color filter. Some five constituents are distinctly visible:

(1) The dark idiomorphic crystal in the middle.
(2) A dark gray portion, extending right and left of the crystal, suggestive of manganese-bearing oxide.

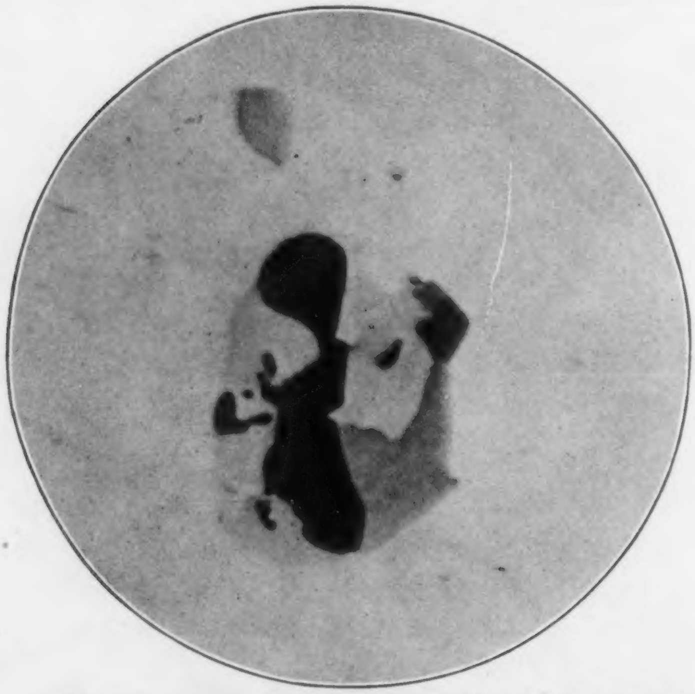


Fig. 122—A Complex Inclusion Showing Complete Separation of Five Different Constitutents. Red Filter. × 2500.

(3) A dove gray area (upper right portion), similar to MnS-rich in FeS.
(4) A very pale gray spot (upper left portion) such as exhibited by the limiting solution of FeS in MnS.
(5) A pale yellow area (lower portion)—FeS proper.

Etching Effects. Etching for 20 seconds by sulphur printing attacked all of the MnS bearing sulphides, and darkened the oxide portions of the eutectic considerably. These oxide portions exhibited, in places, the duplex structure described for S-1A but, on the whole, were found to be more uniform. The oxide in them is of a type rather readily attacked by the acid. This may be

caused by the presence of sulphide in solution in the oxide; it is more likely, however, (in the present case), that the presence of MnO in the oxide accounts for it.

Fig. 123 shows the two types of oxide found in the inclusions,—the darker mottled oxide (attacked by sulphur printing) being the type more frequently represented. This oxide is completely removed on prolonged sulphur printing (2 minutes).

Concluding Remark. The features of the specimen S-6A (and S-6Q) described, do not include the MnO-MnS relationship. The absence, here, of complex MnO-MnS inclusions does not imply that such inclusions cannot exist; it does imply that oxidation at 1795 degrees Fahr. (980 degrees Cent.) in the presence of an excess of FeS, results in the conversion of MnS into MnO which, combined with FeO, makes up the oxide portions of the oxide-sulphide eutectic formed.

What happens at temperatures employed in actual iron and steel making will be shown by the melt SO-2.

The Oxide-Sulphide Melt with Manganese (SO-2)

This melt (SO-2) was prepared by dropping pellets of the mixed oxides of iron and manganese in a remelted portion of S-7 which was originally prepared with the theoretical amount of manganese (to form MnS).

The Effect of Oxide on the Original Inclusions. It will be remembered (see Fig. 81) that a considerable proportion of the S-7 ingot contained dendrites of MnS, while fully 50 per cent of the ingot exhibited the typical clusters of MnS-rich globules. Neither the dendrites, nor the clusters could be found in the melt after the oxide treatment. Instead we have a more or less uniform distribution of fairly coarse rounded inclusions with occasional continuous envelopes (Fig. 124). The majority of the inclusions appear light gray; many are however, distinctly yellowish, suggesting FeS.

Did part of the manganese actually disappear during the melting despite the fact that some was added in the form of oxide, or did the added iron oxide claim some of the manganese from the sulphide? Both possibilities appear to be probable. Preferential oxidation of MnS was indicated already by previously described studies. Discoloration of the crucible walls suggested that they

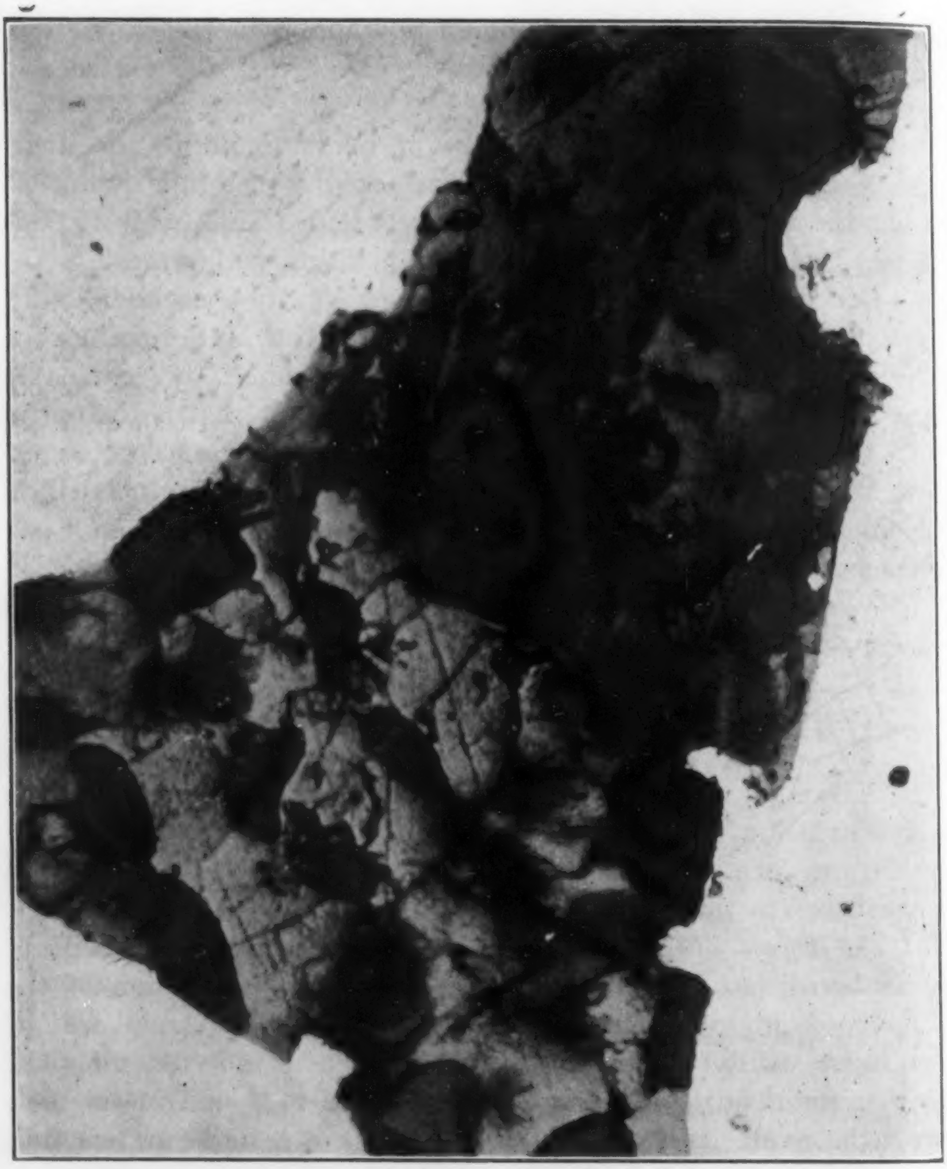


Fig. 123—Portion of a Sulphide-Oxide Stringer After 20 Seconds Sulphur Printing (2 Per Cent Aqueous Sulphuric Acid). Two Oxides Are Present. The Darker One is Pitted by the Treatment. × 2500.

had been attacked by the highly corrosive manganese oxide part of which was thus eliminated from the melt.

Details of the Inclusions. Higher magnification (× 500) shows that about two-thirds of the inclusions are made up of a light gray core surrounded by a shell of a color appearing to be a dark gray. The balance of the inclusions exhibit either a light gray core surrounded by a yellowish envelope, or appear uniformly yellow. These

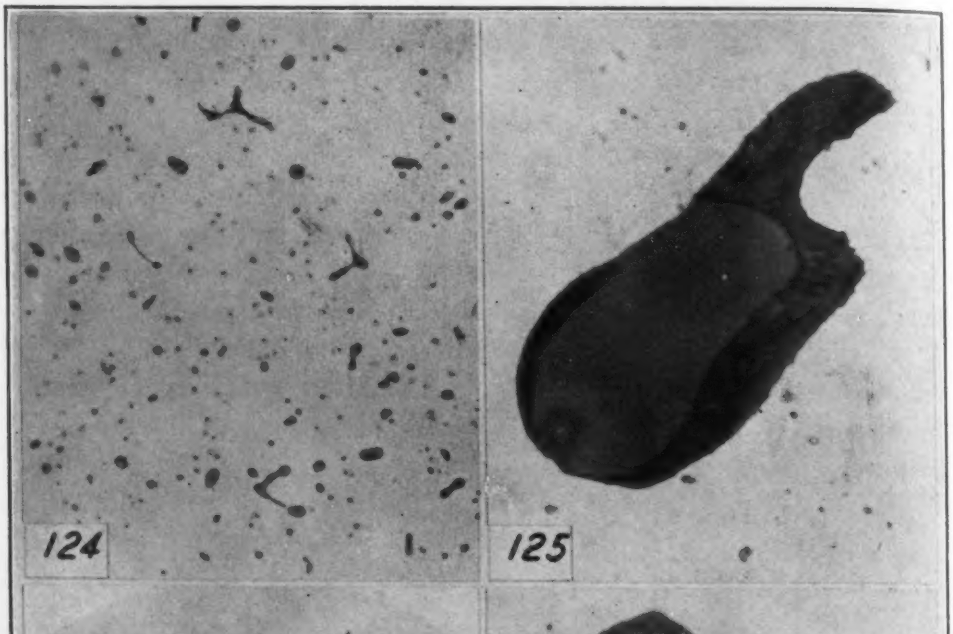
yellow inclusions, at times, show also the dark rim; this is, however, less pronounced than in the case of the gray inclusions.

These relationships are depicted in Fig. 128. The color differences are discernible only with difficulty although a red filter was used in order to emphasize these differences. A careful inspection of the photograph enables one, nevertheless, to differentiate between the gray (darker) inclusions and the yellow ones (lighter). (The inclusions richer in MnS are further differentiated by etching with chromic acid, as shown in Fig. 129.)

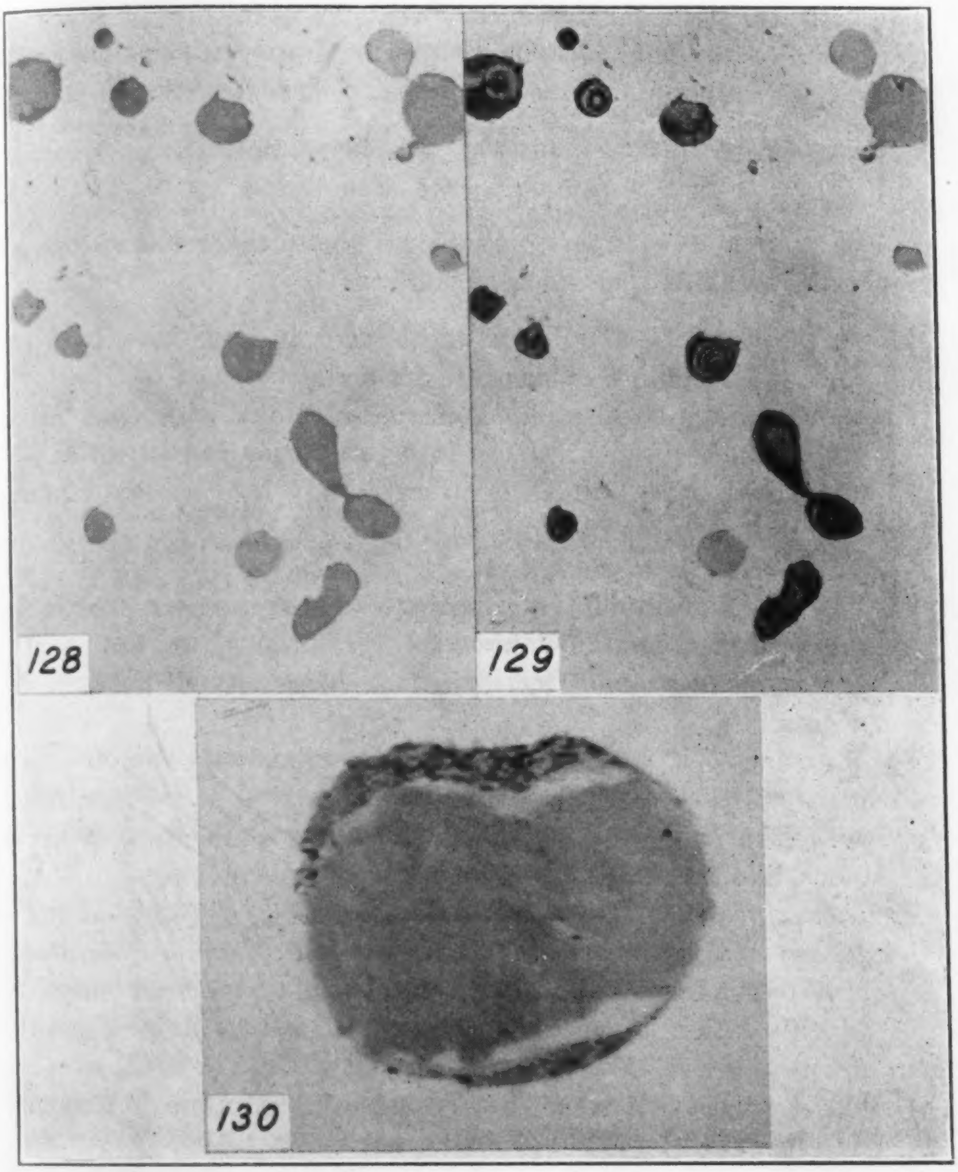
There is no difficulty in observing the dark rims predominantly associated with the gray inclusions. These dark rims, at high magnification ($\times$ 2500), are seen to consist of a eutectic of manganese-bearing sulphide and manganese-bearing oxide. That the sulphide contains MnS is obvious from its dove gray color. The oxide, in turn, must be rich in MnO since it displays a color very much darker than iron oxide. The existence of a MnS-MnO eutectic, similar to the FeS-FeO eutectic is thus definitely indicated.

Figs. 125-127 illustrate the occurrence of this eutectic. Fig. 125 depicts a deep gray inclusion with a eutectic of components of the same gray and of a very much darker gray. In Fig. 126 is shown a light gray inclusion associated with the eutectic and immediately above it a yellowish inclusion carrying a faint gray center part. Note the difference in the amount of the eutectic that has developed in the manganese-bearing inclusion and the inclusion practically devoid of manganese. This difference is further emphasized by Fig. 127, showing two neighboring inclusions of which the lower one is gray, the upper one yellow.

It is evident that manganese-bearing sulphides are attacked by oxide more readily than pure iron sulphide. That manganese, in order to join the oxide, actually gives up its union with sulphur, is beautifully shown by inclusions such as depicted in Fig. 130. A gray kernel of a solution of FeS in MnS is seen to be surrounded by a narrow rim of yellow sulphide which, in turn, is surrounded by a eutectic of yellow sulphide and a very dark oxide. This association indicates clearly what happened. The oxide extracted not only all of the manganese from the sulphide portion of the eutectic, it actually claimed some of the manganese from the body of the main inclusion. It is the portion which has "demanganized" in this manner that constitutes the yellowish areas adjoining the eutectic.



Iron-Manganese Sulphide-Oxide Inclusions in SO-2. Fig. 124—A Typical Spot at × 100. Fig. 125—A Deep Gray FeS-MnS Inclusion Surrounded by the (FeS-MnS)—(FeO-MnO) Eutectic. × 2500. Fig. 126—Lower Inclusion: FeS-MnS + (FeS-MnS)—(FeO-MnO) Eutectic. Upper Inclusion: FeS with Pale Gray Center Part (Limiting Solution of FeS in MnS) and a Small Amount of a (FeS)—(FeO-MnO) Eutectic. × 2500. Fig. 127—Lower Inclusion: as in Fig. 126. Upper Inclusion: FeS with a Small Amount of (FeS)—(FeO-MnO) Eutectic. × 2500.



Iron Manganese Sulphide-Oxide Inclusions in SO-2. Fig 128—Typical Spot at × 500. Fig. 129—Same After Etching for 10 Minutes with 10 Per Cent Aqueous Chromic Acid. The Gray FeS-MnS Sulphide is Destroyed; the Yellowish FeS and the Dark Gray FeO-MnO is Preserved. × 500. Fig. 130—A Light Gray FeS-MnS Inclusion with a Yellow FeS Rim Surrounded by the (FeS)—(FeO-MnO) Eutectic. The Oxide Extracted Some of the Manganese from the Interior Sulphide Portion. Red Filter. × 2500.

The importance of this observation cannot be overlooked. The manganese added to iron or steel acts, first of all, as a deoxidizer, and only such manganese as is in excess of the amount claimed by the oxide becomes available for the sulphur. The beneficial effect on steel of manganese is thus ascribable, primarily, to its de-

oxidizing features (and the fact that FeS, in the presence of manganese is not held in solution by solid iron), rather than to its affinity for sulphur and the "harmless" characteristics of its sulphide.

5. *Summary and Conclusion*

We can now summarize the facts about the relationships of oxide and sulphide inclusions as follows:

I. In the presence of sulphur and oxygen in pure iron, both oxides and sulphides of iron are formed.

II. These oxides and sulphides form solutions with each other which, on cooling, break up into two major constituents:
   (1) a constituent which is either mainly iron oxide, or mainly iron sulphide, and
   (2) a eutectic of these two.

III. In addition, crystals of magnetite (?) are apt to form, and complex sulphide-oxide solid solutions (or fine aggregates), characterized by their lack of resistance to acid reagents.

IV. Manganese, if present in small amounts, will combine primarily with the oxygen; the resulting oxide forms a solution with iron oxide and iron sulphide which, on cooling, behaves much like the oxide-sulphide solution of pure iron.

V. In the presence of considerable manganese, sulphide of manganese will form alongside with the oxide. These (MnS and MnO) form a solution with iron oxide and iron sulphide which solution, on cooling, breaks up into two major constituents:
   (1) a constituent which is either a solid solution of FeS and MnS, or of MnO and FeO, and
   (2) a eutectic of these two.

VI. Complex oxide-sulphide inclusions exhibit varying structures depending on the heat treatment given to the including metal. Quenching, in general, will suppress the formation of the eutectic, and promote fine structures; annealing, on the other hand, promotes coarse structures and a separation of the constituents of the inclusions.

FACTS AND PRINCIPLES CONCERNING STEEL AND HEAT TREATMENT—Part XX[1]

BY H. B. KNOWLTON

Abstract

This is the first of a series of articles on heat treating equipment and methods. Among the subjects discussed are: the fundamental requirements of heating equipment, pyrometers, simple box type furnaces, coal, oil, gas, and electric heating.

HEAT TREATING EQUIPMENT AND METHODS

THE subject of heat treating equipment, although extremely important, must be approached with considerable caution. Each manufacturer of heat treating equipment has some individual ideas. A complete discussion of all of the good and bad points of various kinds of equipment would require volumes, and furthermore such a treatise would be difficult to write without becoming partial to certain kinds of equipment. Obviously it is the writer's desire to be fair and impartial.

In general heat treating equipment may be divided into three general classes: heating equipment, cooling or quenching equipment, and conveying or handling equipment. These may overlap somewhat. For example the conveying equipment may form a part of both the heating and the quenching equipment.

[1]This is the twentieth installment of this series of articles by H. B. Knowlton. The several installments which have already appeared in TRANSACTIONS are as follows: March, June and October, 1925; January, April, May, June, August, October, December, 1926; March, May, July, September, November, 1927; January, May, July, August, 1928.

The author, H. B. Knowlton, member of the Fort Wayne Group of the society, is metallurgist of the Fort Wayne Works, International Harvester Company, Fort Wayne, Ind.

Heating Equipment—Fundamentals of Heating Equipment

Regardless of whether the equipment used for heating is a simple blacksmith's forge or a complicated automatically controlled and operated electric or fuel-fired furnace, the fundamental requirements of correct heating of steel remain the same. Briefly stated they are:

1. The steel should be heated to the desired temperature.
2. It should be maintained at that temperature for the required length of time.
3. It should be heated uniformly. The rate of heating should not be so fast as to cause undue strain. Preferably the heat should not be absorbed by the surface of the steel any faster than it can be conducted into the center of the piece.
4. From a production standpoint the heating should be as rapid as possible without being injurious to the steel heated.
5. From a cost standpoint the heating should be done as economically as possible. This means that the proper source of heat must be selected, and that heat losses should be kept as low as possible. Obviously labor and maintenance costs must also be kept as low as possible.

It is entirely possible for a skillful blacksmith to heat a single tool in an open forge at the correct rate of speed and hold it at the correct temperature for the desired time. This requires skill, experience and judgment. He must determine the temperature by the color of the steel being heated. The apparent color of the steel depends upon the intensity of the light in the room. Needless to say this method is open to many human errors. On production work it has been almost entirely replaced by more foolproof heating furnaces.

The first step from the forge is the placing of a muffle in the fire so that the steel does not come into direct contact with the flames and the hot coal. From this it is only a step to the coal-fired furnaces in which the coal is burned on grates in a long firebox and the flames pass over a bridge wall into an oven in which the work is heated. In such an oven it is possible to heat a large number of pieces more or less uniformly.

Pyrometers

Probably the greatest single step in the development of the modern heat treating furnaces was the introduction of an accurate method of measuring the temperature. This removed the errors of personal judgment and guess work in the control of temperature and made accurate heat treating on a large scale production basis a possibility. At first the instruments for measuring temperature were looked upon with suspicion but now they are universally used in all of the modern heat treating plants.

As the ordinary liquid thermometers are not practicable for temperatures above 700 or 800 degrees Fahr. it is necessary to resort to other means for measuring the higher temperatures of heat treating. While the expansion of solid rods is used somewhat in the measurement of high temperatures, the most common instruments used for this purpose are the electrical and the optical pyrometers. (The word "pyrometer" is the combination of two words, "pyro," meaning fire or heat, and "meter," to measure).

Electrical Pyrometers

The electrical pyrometers are most commonly used for temperatures up to about 2500 degrees Fahr. These may be divided into two main classes: the resistance and the thermocouple pyrometers. The resistance pyrometer depends upon the fact that the resistance of a wire to an electric current varies with the temperature of the wire. Consequently if a small coil of heat resisting wire is inserted in a furnace, and its resistance to electric current is determined it is possible to compute the temperature of the furnace.

Thermocouples

The pyrometers most commonly used in practical heat treating employ the thermocouple instead of the resistance principle for measuring the temperature. A thermocouple consists simply of two wires of different metals which are joined at one end. This junction is usually made by twisting the wires together and then welding them. This end of the couple is inserted in the furnace, consequently it is called the "hot end." The other end of the thermocouple wires which remains outside the furnace is known as the "cold end."

When the welded end of the couple is heated and the other end is kept cool there is a tendency to generate electricity. In order to complete the circuit and allow a current to flow it is necessary that the cold ends of the wires be connected. If the strength or voltage of the current is to be measured it is necessary to have a meter in the circuit. Thus the simplest type of pyrometer consists of a thermocouple connected to a meter (either galvanometer or potentiometer).

The pressure or voltage of the current generated by the thermocouple depends on the metals selected for the two thermocouple wires and the difference of temperature between the hot end and the cold end of the thermocouple. The greater the difference of temperature the higher will be the voltage generated.

It is sometimes stated that the generation of the electric current is due to heating the junction of two dissimilar metals. As a matter of fact if one end of a single wire is heated while the other end is kept cold there is a tendency for electricity to flow from the hot end to the cold end. In order to make a complete circuit it is necessary to have another wire joining the hot and the cold ends. But as one end of the second wire is also hot while the other is cold there is also a tendency for electricity to flow from the hot to the cold end of the second wire. If the two wires are made of the same metal, the voltage of the current tending to flow out each wire will be the same. As the two forces are balanced there can be no current flowing. On the other hand when the wires are composed of two different metals, the pressure or electromotive force in one wire is greater than the other and a current flows. This point is mentioned to emphasize the fact that the current is really due to the difference in temperature between the hot and the cold end of the thermocouple not to an action at the hot end alone.

Theoretically wires of any two different metals might be used, but from a practical standpoint it is obvious that the metals selected must withstand the heat of the furnace without melting, scaling or in any way changing in composition or properties. Furthermore if thermocouples are to be interchangeable it is necessary that the composition of the wires must always be the same. In the early days of pyrometry it was found difficult to produce different batches of metal for thermocouple wires which had the

same composition. At present this difficulty seems to have been overcome.

Among the combinations of metals which are used for thermocouple wires, may be mentioned platinum, platinum-rhodium, chromel-alumel, and iron-constantan. One wire of the platinum, platinum-rhodium couple is pure platinum and the other is composed of an alloy of platinum and rhodium. These couples are very resistant to heat and are used mostly for temperatures from 1800 to 2500 degrees Fahr. Their high cost has caused their use to be limited mainly to measuring temperatures which are higher than other thermocouples will stand. The other couples mentioned are made of cheaper alloys and are commonly used for temperatures below 1800 degrees Fahr.

Meters

The meters used for measuring the voltage generated by the thermocouples at various temperatures may be divided into two classes, galvanometers and potentiometers. A galvanometer is an instrument which contains a needle held on the zero of the scale by a spring. When a current flows through the meter the current tends to make the needle turn. The current is measured by the amount the needle swings. The scale may be divided into millivolts (thousandths of a volt) but more commonly it is graduated to read directly in degrees of temperature.

The deflection of the needle really depends upon the amperes and not the volts. On the other hand the amperes or rate of flow of the current depends upon the volts or pressure and the resistance. The meter reads volts (and consequently degrees) correctly only when the current is flowing through a known resistance. The resistance in the circuit is composed of ''internal resistance'' (in the meter) and ''external resistance'' (in the thermocouple and the line). If the internal resistance is high (400 ohms or more) variations of as much as 1 ohm in the line resistance will only make a slight difference in the total resistance and consequently in the accuracy of the reading. However, if the resistance of the meter is only 4 or 5 ohms a variation of 1 ohm in the line resistance will make a large error in the reading. For this reason if a galvanometer is used for measuring the votage it is best to use a high resistance meter.

The potentiometer also measures voltage or pressure but it works on an entirely different principle. Instead of balancing the strength of the thermocouple current against a spring, it balances the thermocouple current against a battery current of known strength flowing in the opposite direction. Of course the voltage of a dry battery is many times that generated by a thermocouple, consequently the voltage of the thermocouple is balanced against only a small portion of the battery voltage. The battery current passes through a long resistance coil. The current from the thermocouple is passed in the opposite direction through a portion of this coil. By varying the amount of this coil so that the couple current must pass through it is possible to balance the strength of one current against the other. This is usually done by turning a knob on the instrument. A galvanometer on the instrument shows which way the current is flowing When the two are exactly balanced there is no current flowing at all. When the instrument is balanced the galvanometer needle stands at zero. The temperature reading then appears on the dial of the instrument. The advantage claimed for the potentiometer is that the line resistance does not cause an error because there is no current flowing at the time the reading is made.

No matter which system is used it should be remembered that the voltage of the current generated by the thermocouple is very small (never more than a few hundredths of a volt), consequently pyrometers fall in the class of delicate measuring instruments and should be installed and kept up with great care. Many of the troubles which have been experienced with pyrometer systems have been due to careless installation or handling.

Recording and Controlling Instruments

Both the potentiometer and galvanometer systems have been arranged so that the meter not only indicates the temperature but keeps a continuous record of the same. These automatic recording instruments have proven of great value in practical heat treating. Errors in the regulation of the furnace either as to time or as to temperature are apparent on the pyrometer record. Many an honest furnace operator has never appreciated how many irregularities there were in his work until he checked himself with a recording pyrometer.

The controlling recorder is one step in advance of the plain recorder. These instruments have been designed so that they will automatically control the temperature in oil, gas, or electric furnaces. The controller is set for the desired temperature. As long as the temperature of the furnace is below that degree the fuel or electricity is allowed to flow into the furnace. As soon as the temperature rises above the desired figure the heat is automatically cut off. When the temperature drops it comes on again.

In the case of electric furnaces the electricity is usually turned all on or all off by the controller. It is possible, however, to vary the rate of input of electricity depending upon the temperature at which it is desired to operate the furnace. For example the rate of input can be held lower when the furnace is running at low temperatures than when high temperatures are desired. This prevents the heat of the furnace from "drifting" past the desired temperature.

In gas furnaces it is customary to by-pass a small amount of gas around the controller valve, so that when this valve is shut there is still some gas going into the furnace. This is called the "turn down." The amount of the turn down depends upon the temperature and the heating conditions.

Errors in Pyrometer Systems

At the present time meters and couples can be purchased which are reliable, but it is not impossible for errors to appear either in the meter or the couple. In plants having large pyrometer systems it is customary to keep a standard instrument and couple for checking the service instruments and couples. While no rule can be given as to how often checks should be made, it can be said that checks should be made frequently enough to catch errors before they become large enough to be of serious consequence. The accuracy of a single instrument can easily be checked by determining the melting point or freezing point of sodium chloride (common table salt) or some other material with a known melting point.

The check with salt is convenient because salt with sufficient purity is easily obtainable and it has a melting point which is in the range of temperatures used for heat treating. A small crucible containing salt is heated to about 1600 degrees Fahr. This temperature is well above the melting point of the salt. The cru-

cible is then removed from the furnace (or forge) and the thermocouple to be checked is inserted in the melted salt. By watching the meter it will be observed that the temperature falls rapidly until the salt begins to freeze. At this point the temperature remains stationary until all of the salt is frozen. After that the temperature continues to drop. The freezing point of sodium chloride (salt) is 1472 degrees Fahr. If the observed freezing point is not 1472 degrees Fahr. the pyrometer is in error.

In a similar manner the pyrometer may be checked against other salts of known freezing points. For a complete check several temperatures covering the whole heat treating range should be checked. Sometimes a wire of known melting point is hung on a thermocouple in a furnace and the temperature is increased until the wire melts. There are of course other methods of determining the accuracy of pyrometers. The foregoing examples are given as they are simple to perform.

Cold End Correction

As stated before a thermocouple is different from a thermometer in that it does not measure the temperature of one point but the difference in temperature between the hot end and the cold end of the couple. The "cold end" is the point where the thermocouple wires are joined to wires of different electrical properties. For example when copper wires are run from the binding posts of the thermocouple to the meter then the binding posts of the couple become the cold end. As the temperature of the cold end affects the reading it is necessary that the meter be set or compensated for the cold end. By the use of wires of special composition it is possible to extend the cold end to a water cooled box, to some point under ground, to some other point where the temperature is constant, or to extend it to the meter itself. For use with the last mentioned system there are meters on the market which automatically compensate for the cold end temperature.

Position of the Thermocouple

One of the most important factors in determining the success or failure of the pyrometer system in regulating the furnace temperature is the position of the thermocouple in the furnace. Ob-

viously the thermocouple can only measure the temperature of one place in the furnace at a time. Of course if the temperature of all parts of the furnace is the same at all times it does not matter where the couple is placed. On the other hand if the furnace is not uniformly heated, the fact that the pyrometer shows the desired temperature, is no guarantee that the work heat treated receives the same temperature. It is not uncommon to find that a perfect pyrometer record has caused false assurance that the work has been heated properly.

Preferably the thermocouple should be placed as close to the work as practicable. Also it should not be in the direct path of a flame or a current of cold air. Sometimes the thermocouple is placed in a recess in the roof or the wall of the furnace. The temperature of this point is often not representative of the temperature of the work. Sometimes the hole through which the thermocouple is inserted becomes a flue and consequently gets more flame and hot gases than the work. In a natural draft coal-fired furnace, the thermocouple hole becomes a draft hole admitting cold air to the furnace when the chimney damper is open, and a vent letting hot gases out of the furnace when the damper is closed. The remedy for this condition is to pack the thermocouple in the hole so as to prevent a circulation of air or gas in either direction. In a box-type furnace the back wall and the front door are often the coolest parts of the furnace. If the thermocouple is inserted through the back wall or the door it should project far enough into the furnace to reach a zone which is representative of the average temperature of the oven. For the same reason the work to be heated should not be placed too close to the rear wall or the front door. A thermocouple imbedded in a groove in the hearth usually fails to show the temperature of the work. If the furnace is over fired the hearth will usually be the slowest to heat. If it is underfired the temperature in the combustion chamber beneath the hearth is usually higher than the temperature above the hearth. A thermocouple lying in a groove may show too high a reading.

There is no fixed rule for the placing of the thermocouples. Each furnace and heating condition should be studied separately. In large furnaces having a number of burners or heating circuits it may be necessary to use two or more thermocouples. Sometimes a long exploratory couple which can be worked around into

different parts of the furnace is advantageous. The furnace should be carefully studied and the heating should be regulated so as to produce the desired temperature in all parts of the furnace. Preferably the regulation should be made as simple as possible. For example, it may be found that uniform temperatures may be obtained by placing larger burners at certain places in the furnace or by blocking off certain flues. The routine daily operation of the furnace should involve the opening and closing of the fewest possible number of valves.

Optical Pyrometers

Optical pyrometers are most commonly used for measuring temperatures which are too high to be measured by thermocouples other than the expensive platinum, platinum-rhodium type. They are also used for temperatures which are too high for even the platinum couples. The operation of the optical pyrometer depends upon the comparison of the light given off by the furnace or other hot object with a light of known intensity. The standard light used for comparison may be either a small lamp flame or the filament of a small electric light.

One of the common types of optical pyrometers consists of a telescope containing the electric light and a box containing a dry battery and a variable resistance. The wires from the light in the telescope are connected with this battery and resistance box and the telescope is pointed at the inside of the furnace or the hot object whose temperature is to be measured. By turning a knob on the box it is possible to vary the resistance and consequently the amount of current that flows through the lamp filament. The higher the current the brighter the filament becomes. The current is thus adjusted so that the color of the filament exactly matches the color of the furnace. The reading on the dial of the box is then converted into degrees by means of a chart. When very high temperatures are to be measured it is necessary to insert a screen in the telescope to cut down the intensity of the light from the furnace.

For simplicity, one type of optical pyrometer has been described. There are other instruments which are similar in principle but differ in some of the details. Sometimes instead of varying the intensity of the standard light, the intensity of the light

from the furnace coming into the telescope may be reduced by suitable screens until it matches the intensity of the standard light which remains constant.

Optical pyrometer readings are accurate only when measuring the temperature of a "black body," that is, it must measure the light generated by the hot object, not the light reflected by it. A piece of steel in a furnace is a black body, but when it is out in daylight it is not. Readings taken under the latter condition should be corrected for the error. On the other hand, flame and smoke in a furnace will cause an error in the reading.

Optical pyrometers are used in measuring the temperatures in melting and forging furnaces and temperatures of melted metal in the ladle. For such purposes they are very valuable.

Radiation Pyrometers

A radiation pyrometer looks somewhat like an optical pyrometer and is used in a somewhat similar manner but its fundamental principle is different. It consists of a small telescope containing a very small thermocouple. The telescope is pointed at the hot object and the heat radiated from the latter is focussed on the thermocouple. The temperature is read by means of a galvanometer connected with the thermocouple. This instrument like the optical pyrometer should be used under the proper conditions. It should not be held too close to the furnace or hot object and not further away than a certain distance depending upon the size of the opening in the furnace.

Further Advice on Pyrometers

The foregoing discussion of pyrometers has been necessarily brief and somewhat general. It has been attempted to explain some of the general principles rather than to discuss details. For obvious reasons any discussion of relative merits of different systems has been eliminated.

It cannot be said too emphatically that a good pyrometer system is one of the most essential parts of a good heat treating department. There are a number of good pyrometers on the market, but no matter what system is selected, it must be installed and used correctly or it will not give good results. For details

concerning the installation, care and use of pyrometers it is best to get the advice of the maker of the pyrometer.

Coal-Fired Furnaces

After discussing pyrometers which are essential in measuring the temperature of all types of heat treating furnaces, let us return to the discussion of the furnaces. Probably the oldest type of heat treating furnace is the coal or coke-fired oven furnace.

For simplicity a single furnace belonging in this class will be described. The example selected was a home-made furnace which was discarded by its builder about a dozen years ago. Consequently the writer will feel at liberty to discuss it in some detail and point out its faults. It is hoped that such a discussion will help to point out some of the fundamentals concerning heat treating furnaces.

This furnace consisted essentially of two long ovens which were parallel and separated by a bridge wall which did not extend quite up to the roof arch. One of the ovens served as a firebox and had grates extending nearly its entire length. The other oven was the heat treating oven proper. Underneath the fire grates was the ash pit and underneath the heat treating oven was the main flue leading to the chimney. A door in front of the firebox served to admit coal and clean the fire while the door in front of the oven was used for loading and unloading. The flames swept from the firebox over the bridge wall, through the heat treating oven, down vents at either side of the oven floor into the main flue and thence out to the chimney. The fire was controlled by means of a draft door, at the front of the ash pit, a check door at the front of the main flue and a damper between the flue and the chimney.

This furnace proved to be very difficult to control. At first the temperature was judged solely by looking in through a peep hole in the front door. Later a thermocouple was installed in the roof. For a while the pyrometer showed that the temperature was continually varying up and down but eventually the firemen learned that by moving doors and damper a small fraction of an inch at a time they could keep the thermocouple at a constant temperature for several hours during a carburizing run. They bragged

of records which did not show a variation of 10 degrees for hours at a time.

They were merely fooling themselves as many men have done since with more modern furnaces. While the temperature at one spot was kept constant there was considerable variation in different parts of the furnace. Explorations with a long thermocouple showed that there was more than 100 degrees Fahr. variation in different parts of the furnace. Furthermore 15 furnaces built on the same blue prints did not all work alike. Some were hotter in one part and others in another. Even a single furnace did not always work the same. This led to a study of each individual furnace.

Many of the furnaces were cooler near the door. Larger flues were cut at the front end to draw the flames in that direction. At the same time the flues in the hottest parts of the furnace were blocked off. When carburizing boxes were placed too close together the flames and hot gases passed up to the roof but did not circulate around the pots. It was necessary to study the placing of the pots so as to allow an even circulation of gases.

The depth of coal on the grates and the method of firing played an important part, as did also the temperature of the furnace lining. If the lining was soaked through it was much easier to produce a uniform heat than when the charge was placed in a cold or partly heated furnace. With considerable study the heating conditions were much improved, but the control was difficult and open to many errors. On a windy day the fireman was constantly busy with the drafts.

This furnace has been described because it was subject to the greatest number of errors, although with careful operation many of the errors could be eliminated it was far from fool-proof. Coal-fired furnaces have since been improved. The introduction of a forced draft eliminated the errors due to changeable winds. Perhaps a coal furnace could be designed which would eliminate most of the errors mentioned but it is doubted if a coal-fired furnace could ever be made as simple to operate as a modern gas, oil, or electric furnace.

Simple Box Type Gas and Oil Fired Furnaces

One of the first steps away from the old coal furnace was the

introduction of a gas or oil burner in the fire door of a coal furnace. The old firebox became a combustion chamber for the gas or oil. This eliminated the services of a skillful fireman who could keep an even bed of coals over the grates, but sometimes did not improve the uniformity of heating of the furnace oven. The furnace was not designed for the new method of firing and the flames from a single burner in the front of the firebox did not spread out evenly over the entire oven. The only furnaces of this type the writer has observed were not heating as uniformly as the old coal-fired furnaces. This is an example of what frequently happens when it is attempted to change the method of firing without changing the design of the furnace. The next step was the development of the modern box-type gas and oil-fired furnaces.

By a "box-type" furnace is meant a simple oven furnace with a door across the front. It is sometimes called a batch-type or "in and out" furnace to distinguish it from the continuous and other special furnaces. A box-type furnace may be heated with oil, gas or electricity and used particularly when the pieces to be heated are to be given individual care or when the production of any one type of piece is not large enough to warrant continuous furnaces. Small box-type furnaces are used a great deal in tool hardening although some other types of furnaces are also used for this purpose.

The first consideration in selecting a box-type furnace is the size. This depends upon the size and quantity of work to be heated at one time. In general small pieces should be heated in small furnaces and large pieces in large furnaces. The mistake is often made of getting the furnace too small for the work it must handle. If the piece is too large for the furnace it will be difficult to heat it uniformly. On the other hand running a large furnace for a few small pieces is obviously expensive. If the entire hearth of a large furnace is covered with small pieces it may require considerable time and much opening and closing of the door to get all of the pieces out of the furnace and into the quenching tank. This may mean undue scaling.

It is usually best not to place any work too close to the door nor any of the walls, particularly the rear wall, as the extreme front and rear of the furnace are frequently not quite as hot as the center. In a great deal of production work it is necessary to

place the pieces directly on the hearth or floor of the furnace. This is not always so desirable. The bottom of the piece in contact with the hearth at first absorbs heat very rapidly chilling the hearth. After that the top usually heats faster than the bottom.

It should be needless to say that no piece should ever be placed in the direct path of a flame. In some tool hardening it is well to support the pieces above the hearth so that the hot gases may circulate evenly all around the tool. A tool hardener will sometimes move the piece around in the furnace or roll it over so as to make it heat more uniformly. Large axles, shafts and similar parts are sometimes supported on alloy rails laid on or anchored in the furnace hearth. Circular cutters may be supported from the center on refractory cones. These are examples of some of the ways that the uniformity of the heating in box-type furnaces may be improved. In general it is best not to pile pieces too high in a box-type furnace as the top and bottom layers seldom heat at the same rate. This, however, is often done in certain kinds of production work.

It is a good general rule that the work should be heated slowly and uniformly. For production reasons there is often a tendency to heat as rapidly as possible. Just how fast any given piece may be heated without danger depends upon the size and shape of the piece and the nature of the steel. Large pieces must be heated very slowly while smaller ones may be heated faster. In general, low carbon steel will stand fast heating better than tool steel. Some of the alloy steels must be heated very carefully.

It is also a good rule that every piece in the furnace should be uniformly heated and thoroughly "soaked through" at the desired temperature for the required length of time before it is removed from the furnace. It is a common error to misjudge the length of time required to heat a large piece through to the center. Too often a piece is considered to be hot through when the surface shows the color of the furnace. There is so much difference between the speed of heating in different furnaces that no fixed rule can be given which will be reliable. The only sure way is to place a thermocouple in a hole drilled into the center of a piece of a given size and actually determine how long it takes for the center to attain the desired temperature under a particular set of heating conditions. Once this is established it should hold

for pieces of similar size heated under the same conditions. Under "heating conditions" which affect the rate of heating may be mentioned, size of the furnace, character of the furnace lining, temperature of the furnace at the time of charging, length of time the furnace has been at that temperature before charging, weight and temperature of the charge, the rate of flow of fuel (or energy in the case of electric heating) into the furnace and the heat losses through the door and walls.

Method of Firing

In any fuel-fired furnace it is attempted to make the hot gases circulate evenly into all parts of the furnace. The factors that enter into this are the number, position, and size of the burners and the general design of the furnace. It may be necessary to place more burners or larger burners at the cold spots in the furnace or to place vents or flues at such points so as to draw the gases in that direction. It may also be advisable to partially close the values to the burners which are delivering fuel to the hotest portion of the furnace.

Burners have been placed in almost all conceivable positions in the top, bottom, ends and sides of furnaces. The last mentioned condition is probably the most common in box-type furnaces. The side-fired furnaces may be again divided into over-fired and direct-fired and under-fired. In the over-fired furnace the burners shoot into a combustion chamber above the oven of the furnace and the hot burned gases pass down through the furnace. In the direct-fired the flames pass directly into the oven. In this case the burners are usually just below the roof of the oven and the flames shoot almost parallel to the roof. Consequently this type of furnace is sometimes termed an over-fired furnace. The vents or flues are usually placed at the bottom so as to cause the hot gases to pass through the oven. In the under-fired furnace the burners shoot beneath the hearth. The flames and hot gases usually pass up the sides and out vents in the roof. The direct-fired furnace is the simplest to build and the cheapest to repair. On the other hand it is the most difficult to fire properly as the combustion takes place in the heat treating oven. This does not mean, however, that an oven cannot be direct-fired with good results.

The number and size of the burners depends upon the fuel

used, the size of the furnace, the weight of the charge, the temperature to be attained, and the rate of heating desired. In general gas furnaces usually have a greater number of burners than furnaces of the same size which are oil-fired. The amount of fuel delivered by each burner is correspondingly less. The location of the burners from front to back of the furnace must be worked out so as to produce uniform heating. One of the most difficult jobs is to equip a furnace with burners so that it will work equally well on high and low heats.

Gas Versus Oil Firing

The writer does not wish to express a preference in the gas versus the oil controversy. Oil is the cheaper fuel per heat unit delivered. On the other hand oil is the more likely to stop up valves and burners. It is easier to feed gas uniformly to a number of burners on the same manifold. It is impossible to give any figure with regard to costs because the gas rates vary so greatly in different localities. The efficiency of an oil burning system depends upon the oil selected, the type of burners and the way that the firing is controlled. In one plant it may be found that very low cost figures have been obtained while in another plant the costs of oil firing are high. It often happens that due to improper burning the oil is not completely burned. Consequently the oven does not get the benefit of all the heat units in the oil. Some people have reported that preheaters for oil have paid dividends.

Air Supply and Burner Systems

In order to burn any fuel it is necessary that the fuel be mixed with the proper amount of air. When oil is used it is necessary to blow in air with the oil. The oil is also under pressure. It is the function of the burner to "atomize" the oil and mix the proper amount of air with it so that the oil will be completely burned. If too much air is admitted a short intense flame will appear at the burner. If too little air is supplied, flames or smoke will be seen coming from the vents of the furnace. Neither of these conditions represents good heating. The simplest system to explain has an oil valve and an air valve for each burner. Every time the operator changes the oil valve he should also adjust the air valve so that the proper mixture is obtained which will cause

the flames to burn all through the furnace. When a furnace has a number of such valves it requires close watching to keep them all adjusted properly.

A similar system of blower air is used with low pressure gas. Frequently one pair of valves is used to regulate the air and gas for a manifold supplying a number of burners. When high pressure gas (8 to 15 pounds) is used with proper burners, blower air is unnecessary. The high pressure gas sucks in the proper amount of air through a mixer on the burner.

The trend of modern design of both gas and oil systems is to make the system as simple as possible. Preferably a single furnace should be controlled by the fewest number of valves possible. In one of the low pressure gas systems the gas is reduced to zero presure pust before it enters the mixer. The air syphons the gas into the burner. Thus the only valve which has to be controlled is the air valve. There are also a number of other single valve systems which work satisfactorily.

It is impossible to describe all of the systems on the market or to go into any of them in detail. It has been attempted merely to give some of the general ideas concerning burner and valve systems. All discussion of the details of burners has been purposely omitted. The best information on this subject can be obtained from the manufacturers of the equipment. Suffice it to say that the burnering of a furnace is a real engineering problem. The day has passed when a heat treating furnace is a pile of bricks with a gas and air, or oil and air pipe stuck into it.

Automatic Control

Today there are several automatic control systems on the market which will regulate either gas or oil-fired furnaces. This is a big step in advance as it eliminates the errors of human operation. Of course the automatic controllers must be properly installed and maintained. They constitute a great help in accurate heat treating but not a cure all. The automatic controlling device is attached to the pyrometer (either potentiometer or galvanometer type). These controllers have already been described.

Electric Box-Type Furnaces

Electric heating was probably first applied to the simple box-

type furnaces. At least 16 or 18 years ago there were small electric tool hardening furnaces on the market. The electricity was passed through heat resisting wires surrounding the oven of the furnace. If the furnace was designed properly it would heat uniformly at all times. The operation was very simple, consisting merely of varying the amount of current flowing through the furnace. When the furnace was once regulated for the correct temperature it would hold a uniform temperature as long as the line voltage remained constant. These made excellent furnaces and they are still in common use. Automatic recorder controllers have been added in more recent years which almost eliminate the human error from the control of the temperature.

At first it was thought that on account of the cost, electricity would be limited to tool hardening, laboratory and experimental work. In many localities electricity is the most expensive form of heat energy. Of course there are some localities where electrical energy is very cheap.

The designers of electric furnaces early appreciated that if electric heating was to be applied to large furnaces for production heat treating it would be necessary to improve the heat efficiency of the furnaces. This meant a study of furnace design and particularly of heat insulation. The electric furnace has the obvious advantage over the fuel-fired furnaces in that there is no current of cold air and fuel entering the furnace and hot gases leaving the furnace. But what could be done to diminish the heat losses through the walls and the doors?

Some of the old heat treating furnaces of a decade or two ago consisted primarily of an iron shell with one or more layers of firebrick between the shell and the oven proper. The heat losses through the walls of such a furnace are enormous. While refractory firebricks around the oven of a high temperature furnace are essential in order to withstand the heat, it has been found that by placing a proper insulating material between the refractory and the outside walls, the heat losses could be cut down to the minimum. A well insulated electric furnace sometimes shows a lower heating cost than a poorly insulated fuel-fired furnace.

It is probably unfair to give the electric furnace designers the entire credit for the development of the modern well-insulated furnace. They were among the first but others were working on

the problem at the same time. Today there are fuel-fired furnaces on the market which are as well insulated as the electric furnaces.

The question is often asked, "which is the cheapest furnace to operate, an electric or a fuel-fired furnace." The answer will depend upon the design of the furnace, the heating operations to be performed and the local costs of gas, oil and electricity. At first the durability of electric furnaces was questioned, but today there are heating elements which have as long a life as the rest of the furnace.

When metal heating elements are used, the furnace temperature should not be allowed to exceed 1700 or perhaps 1800 degrees Fahr. Quite recently nonmetallic heating elements have been designed for furnaces which are to be run as high as 2500 degrees Fahr. It may be a little early to comment on these, although it should be safe to predict that high temperature electric furnaces will be more common in the future than they are now.

It may be as well not to comment on which furnace produces the best results, gas, oil or electric. All of them will produce good results if designed and operated correctly. It can be said emphatically, however, that the modern furnace is far superior to the furnace of a few years ago.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Discussion in This Column

REPLY TO WRITTEN DISCUSSION OF A. B. KINZEL'S PAPER ENTITLED "STEELS FOR CASE NITRIFICATION"

By A. B. Kinzel[1]

Mr. OSTERMAN'S remarks are most interesting and quite pertinent. It is regrettable that he has not been able to test the vanadium nitrogenizing steels in order to compare them with others of the great variety which he has tested.

Mr. DeFries' remarks are also appreciated. It is interesting to note that the manufacture of aluminum-bearing steels has now been perfected.

Regarding the degree of hardness obtained on nitrifying vanadium steels, the author has pointed out that a minimum of some 0.4 per cent vanadium in solid solution is necessary for maximum hardness. Possibly Mr. DeFries' tests were performed on steels with lower vanadium content.

Regarding the measurement of hardness, Mr. DeFries has probably misread the tables, at the bottom of which it is definitely stated that 67 Rockwell "C" is given merely because that is the highest Rockwell number in the author's experience and that the hardness is undoubtedly greater than this. The 900 Brinell was obtained by the interpretation of scratch hardness tests. Since the paper has been presented, the Herbert pendulum tester has been used and results of 1000 Brinell consistently obtained.

The author agrees entirely with Mr. DeFries as to the practicability of incorporating the required alloys into the steel itself when this is possible, as against infusing them into the surface, other things being equal.

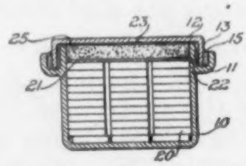
[1]A. B. Kinzel, "Steels for Case Nitrification," Transactions, American Society for Steel Treating, Vol. XIV, August, 1928, page 248. The author's reply to the written discussion accompanying the paper was received too late for printing with the paper.

Reviews of Recent Patents

By NELSON LITTELL, Patent Attorney
475 Fifth Ave., New York City—Member of A. S. S. T.

1,673,271, Method of Annealing, Clarence Ross Gale Stewart, of La Grange, Illinois, Assignor to Western Electric Company, Incorporated, of New York, N. Y., a corporation of New York.

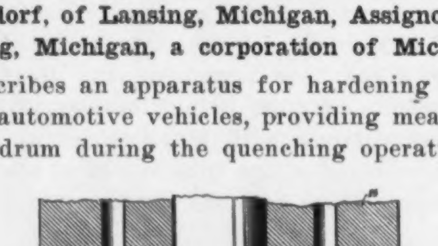
This patent describes a method of annealing in which the parts 20 to be annealed are packed into a suitable annealing box 10 on the top of which a material, such as electrolytic iron dust 23, capable of generating a



reducing atmosphere, is inserted and the lid 12 is placed upon an annealing box and sealed by the use of loam or the like 15. Upon heating, the hydrogen is driven off from the electrolytic iron dust 23 and combines with the oxygen driven off from the parts 20 so as to prevent oxidization of the parts 20 and also improve the quality of the iron dust 23.

1,674,470, Method and Apparatus for Hardening Brake Drums and the Like, Walter G. Hildorf, of Lansing, Michigan, Assignor to Reo Motor Car Company, of Lansing, Michigan, a corporation of Michigan.

This patent describes an apparatus for hardening the braking surface of brake drums for automotive vehicles, providing means for retaining the shape of the brake drum during the quenching operation and for protect-

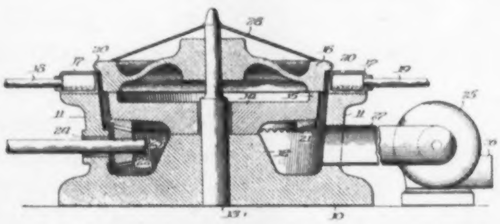


ing the web. The apparatus comprises a base 11, a plurality of segments 12 movable radially upon said base, the segments having inner cam surfaces 15 co-operating with the cam surface 14, and a plunger 13 for moving the radial segments 12 outwardly. In the operation of the device the brake drum 10 is placed over the segments 12 with the web resting in the recess 18 and the plunger 13 is brought down to expand the segments 12 into contact with the interior of the drum and to bring the plate 22 against the web of the drum to protect the same. The entire apparatus, including

the base plate 11, is then immersed in a quenching fluid which flows upwardly through the openings 23 around the outside of the drum and through the grooves 21 on the inside of the drum and out through the passages 28, 29 and 30. After the removal of the drum from the quenching bath strippers 33 are provided for stripping the cooled drum from the segments 12.

1,674,884, Apparatus for Cooling Car Wheels, John Brunner, of Chicago, Illinois.

This patent describes an apparatus for cooling the tread and flange of cast and forged steel car wheels to harden the tread while protecting the web from hardening influence. The apparatus comprises a base 10 with an upstanding flange 11 and a central pedestal 12 in which a spindle 13



is located. Resting on the pedestal 12 and surrounding this spindle 13 is a rotatable supporting member 14 having a rim 15 of a slightly less diameter than the diameter of the car wheel. The car wheel 26 is placed upon the supporting member 14 which may be rotated by the shaft 23 and gear 22 and the tread and flange are subjected to the cooling influence of the water cooled ring 17 and to a blast of air forced into the bowl formed by the flange 11 from the fan 25.

1,675,190, Manufacture of Mild-Steel Plates, Sections, and the Like, Francis Grimshaw Martin, of Higher Bebington, England.

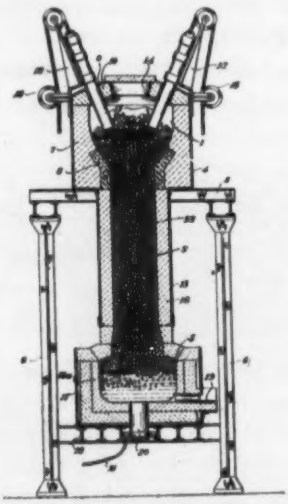
This patent is for a process of manufacturing mild-steel plates for bridges, girder work, buildings and the like, in which the unequal elastic limit of the plate caused by rolling or forging is removed by heating the plate throughout to a temperature of 1470 to 1650 degrees Fahr. (800 to 900 degrees Cent.) and rapidly cooling the same by causing currents of air to pass over the surface or immersing them in a suitable quenching solution. The plates may then be tested by subjecting the edge trimmings cut from the edges or margins of the plates to an appropriate test, making it unnecessary to assume large factors of safety in plate structure.

1,675,644, Age-Hardening Process, Reginald Scott Dean, of La Grange, Illinois, and William Ewart Hudson, of Los Angeles, California, Assignors to Western Electric Company, Incorporated, of New York, N. Y., a corporation of New York.

This patent desribes a process of age-hardening lead alloys, particularly for the making of storage battery grids in which after casting the alloy is heated to obtain a solid solution, cooled and subjected to a working operation, then reheated to the solid solution temperature and quenched and permitted to age. The second reheating, after working, gives a less brittle alloy.

1,675,744, Shaft-Type Electric Furnace, Thaddeus F. Baily, of Alliance, Ohio.

This patent describes a shaft-type of electric furnace various modifications of which are adapted for the manufacture of synthetic pig iron, the production of silicon direct from SiO_2; the production of silicon carbide from SiO_2 and carbon; and the production of amorphous graphite from amorphous carbon. Four embodiments of the furnace are illustrated in



each of which the furnace proper consists of a shaft, such as indicated at 15, provided with a suitable refractory lining 16 and with electrodes 11 and 20 located at opposite ends of the shaft, the charge 22 forming a resistance between the electrodes by which the temperature of the inside of the shaft may be kept at the desired point. The molten material is collected in the crucible 18 at the base of the shaft and discharged through the spout 19. In the other modifications, means are provided for charging the furnace through hollow electrodes and means are provided to burn the combustible gases given off in the furnace shaft in a preheating chamber to preheat the charge which is being fed into the shaft.

1,673,951, Rust Removing and Preventing Composition, Edward J. Rogers, of Miamisburg, Ohio, Assignor to The Westerfield Pharmacal Company, of Dayton, Ohio, a corporation of Ohio.

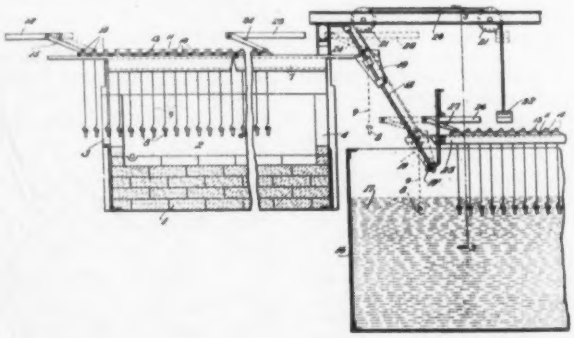
This patent describes a rust removing and rust preventing composition, comprising soluble cotton (pyroxylin, $C_{12}H_{16}$ (ONO_2) $4O_6$) 1 per cent, acetone (C_3H_6O) 3 per cent, amyl acetate $(C_7H_{14}O_2)$ 3 per cent, phosphoric acid (H_3PO_4) 24 per cent and ethyl acetate $(C_4H_8O_2)$ 69 per cent, which may be applied to the metal by a brush and then rubbed in with waste to remove rust, acid and the like from the surface and permitting the surface to be painted within an half hour after the composition is applied.

1,675,798, Alloy and Process for Making Same, Russell Franks, of Brooklyn, and Burnham E. Field, of Douglaston, New York, Assignors to Haynes Stellite Company, a corporation of Indiana.

This patent describes a high-speed cutting alloy of the type described in the Cooper patents Nos. 1,221,769, 1,277,046, 1,278,304, 1,350,359, and 1,461,178 in which the hardness of the alloy is secured by raising the zirconium content and decreasing the aluminum content, thereby reducing the oxidization of aluminum and avoiding the segregation of tungsten, such as is experienced in the preparation of the previous alloys of this type. The hardness of the alloy is also increased by the presence of boron which brings about a marked refinement of grain structure. The alloy, according to the present invention, consists of 5 to 12 per cent tungsten, 6 to 12 per cent zirconium, 3.5 to 6 per cent silicon, 3 to 5 per cent aluminum and up to 1 per cent boron, the balance principally nickel.

1,675,795, Discharging and Quenching Mechanism for Furnaces, Frank T. Cope, of Salem, Ohio, Assignor to The Electric Furnace Company, of Salem, Ohio, a corporation of Ohio.

This patent describes a quenching apparatus for continuous heating furnaces, such as indicated at 1, in which the articles 8 to be heat treated are moved through the heating zone 2 by means of the reciprocating push rod 14 which pushes the slides 13 in which the articles 8 are supported by the wires 9 in a step by step movement through the furnace from the



charging door 3 to the discharge door 4. Adjacent to the discharge door 4, a second reciprocating push rod 23 quickly transfers the articles from the furnace 1 to the elevator mechanism 19 from where they are automatically lowered on the rods 18 into the quenching bath 16 and moved in a step by step movement by the push rod 26 from the elevator 19 through the quenching bath. By moving the articles rapidly from the point spaced from the discharge door 4 into the quenching solution, the articles can be quenched at the desired temperature without the usual cooling which takes place in transferring the articles from the furnace to the quenching bath.

1,672,862, Firing Arrangement for Muffle Furnaces. William J. Harris, Jr., New York, N. Y., assignor to The Surface Combustion Company, Inc., Toledo, Ohio.

Heating gases are introduced below a muffle in the furnace chamber in a direction transverse to the length. A portion of the heating gases is diverted back to the side wall nearest the entrance of the gases.

THE ENGINEERING INDEX

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Arrangements have been made with The American Society of Mechanical Engineers whereby the American Society for Steel Treating will be furnished each week with a specially prepared section of The Engineering Index Service. It is to include items descriptive of articles appearing in the current issues of the world's engineering and scientific press of particular interest to members of the American Society for Steel Treating. These items will be selected from the Weekly Card Index Service of the Index published by the A. S. M. E.

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AIRCRAFT

METALLURGY. Progress of Metallurgy and Influence on Aeronautics (Progrès de la metallurgie et leur influence sur l'aéronautique, G. Py. *Société des Ingénieurs Civils de France (Paris) Mémories,* vol. 81, no. 1 and 2, Jan. and Feb. 1928, pp. 113-170, 29 figs. partly on supp. plates.

Metallurgy in general, working and use of metals with particular application to metallic construction of airplanes; steels for engines.

ALLOYS

HARDENING. The Slip Interference Theory of Hardening, M. G. Corson. *Min. and Met.,* vol. 9, no. 259, July 1928, pp. 314-316.

Alloy to be amenable to age or heat hardening should contain among its components some that will stay in solid solution at high temperatures and precipitate as secondary phase on cooling; this secondary phase may be either more or less pure individual element (chromium in case of copper, antimony in case of lead), or some intermetallic compound; maximum hardness obtained with fixed amount of precipitable matter depends on proper balance of number of particles and their size.

ALLOY STEELS

MANUFACTURE. The Manufacture of Alloy Steel, E. C. Smith. *Am. Metal Market,* vol. 35, no. 111, June 12, 1928, pp. 20-22, 43 and 47.

Discusses important phases of those steels whose tonnage has established them as production materials; type of pig iron most suitable; alloy steels are dependent upon special elements for their peculiar properties; special elements involved; probable future combinations. Paper read before Am. Iron & Steel Inst.

VOLUMETRIC DETERMINATION. Persulfate Method for Chromium Plus Vanadium in Chrome-Vanadium-Tungsten Steels, H. H. Willard and P. Young. *Indus. and Eng. Chem.,* vol. 20, no. 7, July 1928, pp. 769-770.

Persulphate method was chosen as simplest and most commonly used, and in procedure which is described directions for chromium in presence of tungsten are given.

VOLUMETRIC DETERMINATION. Vanadium in Chrome-Vanadium-Tungsten Steels, H. H. Willard and P. Young. *Indus. and Eng. Chem.,* vol. 20, no. 7, July 1928, pp. 764-768.

Vanadium is determined without separation from tungsten, chromium, molybdenum, and iron by selective oxidation with bromate in solution containing ammonium salts and definite concentration of hydrochloric acid; excess of bromate is removed by boiling and vanadic acid titrated electrometrically with ferrous sulphate; tungstic acid is kept in solution by dissolving it in solution to which sufficient ferric sulphate has been added; in this soluble form it does not interfere.

ALUMINUM ALLOYS

Metals and Alloys (Metalle und Legierungen), Masing. *V. D. I. Zeit. (Berlin),* vol. 72, no. 23, June 9, 1928, p. 787.

Brief annual review of progress in production of aluminum and copper alloys; scientific research in alloys.

AIRCRAFT. "Laboratory" Light Alloys and Their Production Commercially. *Flight (Lond.),* vol. 20, no. 25, June 21, 1928, pp. 470-471, 7 figs.

System employed by High Duty Alloys,

Those members who are making a practice of clipping items for filing in their own filing system may obtain extra copies of the Engineering Index pages gratis by addressing their request to the society headquarters, whereby their names will be placed on a mailing list to receive extra copies regularly.

Ltd. in producing high-tensile aluminum alloys; Hiduminium, Y and DV alloys, made to D.T.D. specification 18A, are supplied to British and foreign aircraft firms; alloys produced under ideal conditions; extraordinary care and control maintained from beginning to end; works are large-scale laboratory rather than foundry and laboratory methods are employed throughout; daily record of foundry melting.

CASTING. Aluminium Casting Alloys, G. Mortimer. *Foundry Trade Jl. (Lond.)*, vol. 38, nos. 617 and 618, June 14 and 21, 1928, pp. 431-432, 437, and 458-460, 8 figs.

Real progress of past ten years lies not so much in discovery of new alloys, as in methods of dealing with them after they are alloyed; essence of Archbutt method lies in allowing metal to solidify in melting pot, and immediately on solidification to bring it up to pouring temperature again. See also Metal Industry (Lond.), vol. 22, nos. 24 and 25, June 15 and 22, 1928, pp. 593-596 and 612-614.

CASTINGS. Effect of Melting and Pouring Conditions Upon Aluminum Castings, T. W. Bossert. *Fuels and Furnaces*, vol. 6, no. 7, July 1928, pp. 895-896.

Tests were carried out in laboratories of Aluminum Company of America; plan of this work required tests for two effects, draws and crystal size; no logical explanation for phenomena which have been discussed has been found. Abstract of paper presented at Am. Foundrymen's Assn.

HEAT TREATMENT. Heat Treatment of Aluminum and Its Light Alloys, R. J. Anderson. *Fuels and Furnaces*, vol. 6, no. 7. July 1928, pp. 901-902.

Equipment for heat treating of aluminum and aluminum-alloy products; furnaces for annealing wrought aluminum, e. g., sheets, coil, circles, wire rods, and other semi-finished products. (Continuation of serial.)

AUTOMOBILE DRIVE

DRIVE SHAFT MANUFACTURE. The Automobile Drive Shaft, R. L. Rolf. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 1, July 1928, pp. 72-80, 14 figs.

Author briefly outlines in non-technical manner manufacture of automobile drive shaft, touching upon such features as design, forging, machining, testing, physical properties and materials used; shows advantage of using molybdenum steel to obtain easy machinability at high Brinell hardness, thus enabling shafts to be completely machined in heat treated state.

AUTOMOBILE PLANTS

HEAT TREATING DEPARTMENT. Heat Treating Shops of the Willys-Overland Factory at Toledo, U. S. A. (Les ateliers de traitement thermique des usines d'automobiles Willys-Overland, a Toledo (E.-U.). *Génie Civil (Paris)*, vol. 92, no. 2392, June 16, 1928, pp. 577-581, 8 figs.

Description of shops for heat treating automobile parts, layout of equipment; routing of work; furnaces used and parts treated.

HEAT TREATING DEPARTMENT. Treating Ford Model "A" Parts, F. L. Faurote. *Iron Age*, vol. 122, no. 1, July 5, 1928, pp. 12-15, 4 figs.

Heat treatment schedule for Ford Model A shafts, axles and gears; continuous gas and electric furnaces handle production; furnaces put wherever needed in production line; double-deck furnace saves space; uniform temperatures in gas furnaces; treatment of 1 per cent chromium steel; case hardening chromium-vanadium steel.

AUTOMOBILES

BODIES, STEEL. Sheet Steel for Automobile Bodies. *Heat Treating and Forging*, vol. 14, no. 6, June 1928, pp. 613-617, 2 figs.

Equipment and methods of pickling and cold rolling steel sheets; chemical action in pickling; physical changes resulting from cold rolling; factors concerning acid solution; regulation of solution, rinsing and scrubbing. (Continuation of serial.)

BEARINGS

FORGING BALL RACES. Forging Races for Ball Bearings, J. C. Kielman. *Am. Mach.*, vol. 68, no. 26, June 28, 1928, pp. 1029-1031, 6 figs.

Some difficulties encountered in forging rings for ball races by upset process; forging machines, furnaces and methods in New Departure Mfg. Co. plant; erosion of dies is greatest difficulty; forging temperature closely controlled; how variations in temperature of stock affect length of forgings; wear of upsetting die.

BRIDGES, STEEL

TESTING STRUCTURAL MEMBERS. Tests of Structural Members for Sydney Harbour Bridge. *Engineering (Lond.)*, vol. 125, no. 3256, June 8, 1928, pp. 697-698, 9 figs. partly on supp. plate.

One requirement called for in contract was that numerous tests of full-size members, and of large-scale models of important members, should be carried out; for this purpose, contractors ordered largest universal testing machine, in which loads are actually weighed, that has so far been constructed; gives three examples of work of machine.

CASE HARDENING

Selective Case Hardening, C. B. Gordon-Sale. *Machy. (Lond.)*, vol. 32, no. 821, July 5, 1928, p. 445.

Methods of case hardening a component in such a way as to leave some sections soft; processes for selective case hardening; nonmetallic coatings and methods of their removal; for all fine quality work, protection by means of electrodeposited copper plate forms best method of selective case hardening.

CARBURIZING. Carburizing with Mixtures of Hydrogen and Natural Gas. W. P. Sykes. *Fuels and Furnaces*, vol. 6, no. 7, July 1928, pp. 913-918, 20 figs.

For a given concentration of methane in hydrogen, temperature of heating and a consequent diffusion rate of carbon through iron is most important factor governing thickness of carburized shell; experiments on Armco Iron; construction of furnace; variation of temperature and atmosphere; factors governing depth of carburization.

CARBURIZING. Carburizing and Case Hardening. *Heat Treating and Forging*, vol.

14, no. 6, June 1928, pp. 626-629.

Definitions, history and results to be attained are reviewed; important factors involved are discussed and different processes described; hardening versus case hardening; discusses fundamentals of carburizing and case hardening; principles on which results of case hardening are well standardized; important consideration of temperature at which carburizing is done; box carburizing. (To be continued.)

CARBURIZING. Facts and Principles Concerning Steel and Heat Treatment, H. B. Knowlton. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 1, July 1928, pp. 127-148.

Discussion of solid carburizing materials, method of packing carburizing, carburizing protection, reuses of carburizing materials, carburizing furnaces, carburizing containers, gas carburizing, and methods of control of depth of case; action of base materials and chemical energizers in carburizing compounds is explained.

NITRATION. Cylinders and Crankshafts for Automobile and Airplane Engines Hardened by Nitridation (Cilindros y ciguenales para motores de automobil y aeroplane, endurecidos por nitruracion), G. Nunez. *Revista Minera (Madrid)*, vol. 79, no, 2131, May 24, 1928, pp. 247-248.

Process of surface hardening of special steels by formation of nitride iron on surface of metal; tests made by Hispano-Suiza and others; comparative results on treated and untreated cylinders, crankshafts, etc., indicate lowering of engine weights and sales prices, with increased resistance to wear.

CAST IRON

CHILLS. Internal Chill in Cast Iron, J. E. Hurst. *Iron and Steel Industry (Lond.)*, vol. 1, no. 10, July 1928, pp. 301-303, 1 fig.

Causes of internal chill discussed and latest views on its influence on segregation, hard spots and other features are summarized; connection with chemical composition and rate of cooling at surface and interior; inverse segregation.

ELECTRICAL CONDUCTIVITY. The Electrical Conductivity of Cast Iron, H. Pinsl. *Iron and Steel Industry (Lond.)*, vol. 1, no. 7, Apr. 1928, p. 224.

Study of electrical conductivity of cast iron; factors which govern specific resistance; influence of phosphorus, manganese and sulphur. Abstract translated from Giesserei—Zeitung, no. 3, 1928.

ELECTRIC FURNACE MELTING. Making Cast Iron in the Electric Furnace. *Iron and Steel Industry (Lond.)*, vol. 1, no. 9, June 1928, p. 279.

Discussion of report by Bureau of Mines regarding comprehensive investigation of making of electric-furnace cast iron; year's operation of jobbing foundry making miscellaneous gray-iron castings from steel scrap; electric-furnace cast iron stronger, tougher, and more dense than cupola iron, and higher recovery of metal in casting.

GRAPHITIZATION. Graphitization of Cast Iron, R. Stumper. *Iron and Steel Industry (Lond.)*, vol. 1, no. 8, May 1928, pp. 247-249.

Discussion of article entitled "Die Spongiose des Gusseisens," appearing in Korrosion und Metallschutz; graphitization of cast iron is one of most typical examples of selective corrosion; chemical constitution; earlier investigations; graphitic disintegration in grey cast-iron pipes.

GRAPHITIZATION. Graphite in Gray Cast Iron and Its Influence on Strength (Beitraege zur Kenntnis des Graphits im Grauen Gusseisen und seines Einflusses auf die Festigkeit), P. Bardenheuer and K. L. Zeyen. *Mitteilungen aus dem Kaiser-Wilhelm-Institut fuer Eisenforschung (Duesseldorf)*, vol. 10, no. 3, 1928, pp. 23-53, 176 figs, partly on supp. plates.

Full report of investigations carried out at Technical Academy of Aachen, previously annotated.

IMPROVEMENT. High-Grade Cupola Cast Iron (Hochwertiges Kupolofengusseisen), F. Dengler. *Zeit. fuer die Gesamte Giessereipraxis (Berlin)*, vol. 49, nos. 26 and 27, June 24 and July 1, 1928, pp. 221-223 and 229-231, 17 figs.

Author points to uncertainty in continuous production of uniform material; main factors of homogeneous structure are burden, degasification of charge, and cooling conditions of castings; discusses means and methods of improving structure.

NICKEL. The Future of Alloy Cast Iron. *Foundry Trade Jl. (Lond.)*, vol. 38, no. 617, June 14, 1928, p. 430.

It is clear that to produce very best results from alloy addition; conditions under which it should be used must be well understood; basis of development must lie in control of cast iron itself before it leaves melting furnace; general effect of nickel on cast iron.

PEARLITIC. High Grade Cast Iron (Hochwertiges Gusseisen), H. Jungbluth. *Kruppsche Monatshefte (Essen)*, vol. 9, May 1928, pp. 69-92, 29 figs.

Complication reviewing European and American literature, to end of 1927, on methods of making and properties of pearlitic and other special high-grade varieties of cast iron; international bibliographic list of 143 items.

PEARLITIC—PROPERTIES. Perlit Iron, G. Meyersberg. *Eng. Progress (Berlin)*, vol. 9, no. 6, June 1928, pp. 153-157, 14 figs.

Review of historical development; strength, toughness, machining properties; freedom from stresses, uniformity of structure freedom from piping and similar segregations, density, resistance to wear, permanence of structure at higher temperatures; new process, discovered by Sipp, and worked out at Heinrich Lanz's (Mannheim) foundries, for improving properties of cast iron by adopting suitable mixture and controlling rate of cooling according to mixture used.

RESEARCH. Silicon-Carbon Sum Is Factor in High-Duty Cast Iron Production, A. Levi. *Foundry*, vol. 56, no. 12, June 15, 1928, pp. 479-480.

Study of high-duty cast iron; problem is to eliminate graphite as much as possible and to obtain its division in fine lamallae; 3 per cent of total carbon is most satisfactory composition to be aimed at; addition of steel to charge has no bad effects

if melting operation has been performed properly. Abstract from paper presented before Assn. Technique de Fonderie.

TEMPERATURE EFFECT. Properties of Cast Iron at Low Temperature (Les propriétés de la fonte à basse température), *Fonderie Moderne (Paris)*, vol. 22, May 25, 1928, pp. 200-202.

Chemical analyses of various samples and tests for tension and bending.

TESTING. Engineering Tests for Cast Iron, J. G. Pearce. *West of Scotland Iron and Steel Inst.—Jl. (Glasgow)*, vol. 35, part 5, Feb. 1928, pp. 80-90, 4 figs. partly on supp. plates.

Considers mechanical tests for cast iron from point of view of metallurgical desirability and practical convenience; indicates briefly logical development of considerations which have resulted in new specifications; shape of test bar; respective merits and demerits of tensile and transverse test; shear test; relations between tests.

TESTING. Colorimetric Methods in the Foundry Laboratory, H. Freund. *Foundry Trade Jl. (Lond.)*, vol. 38, no. 618, June 21, 1928, p. 460.

Particulars regarding the reactions and procedure employed for colorimetric determinations in use for a considerable time in German iron and steel works and which recommend themselves for foundry laboratory; determination of combined carbon in pig iron and cast iron; determination of manganese, copper and titanium. Abstract translated from Giesserei, Feb. 10, 1928.

CASTINGS

CLEANING. Cleaning Room Progress Aids Production of Quality Castings, F. G. Steinebach. *Foundry*, vol. 56, nos. 12 and 13, June 15 and July 1, 1928, pp. 481-484 and 546-548 and 554, 16 figs.

June 15: Applications of sand blasting in foundry cleaning room; automatic, rotary sand-blast table adapted especially to cleaning castings requiring special care to prevent breakage; gravity-feed type unit of compact construction which requires no pit or special foundation; pressure-type machine uses two tanks; sand-blast cabinets. July 1: Application of mass-production methods.

CLEANING. Cleaning Room Progress Aids Production of Quality Castings, F. G. Steinebach. *Abrasive Industry*, vol. 9, no. 7, July 1928, pp. 187-192, 25 figs.

Complete treatise on cleaning-room practice, describing machines and methods comprehensively.

CHROMIUM STEEL

REFINING. Refine Chrome Steel at Low Heat, N. N. Menshih. *Iron Age*, vol. 121, no. 26, June 28, 1928, pp. 1817-1818.

Low temperature essential in basic open-hearth furnace if chromium-bearing scrap is used and if high ballistic tests must be met; deleterious effect of chromium when present from beginning of heat mitigated considerably if certain properties of element and its slag-forming oxides are known and provided for; residual chromium depends upon furnace practice.

CHROMIUM-NICKEL STEEL

A Note on the Hardness and Impact Resistance of Chromium-Nickel Steel, B. F. Shepherd. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 1, July 1928, pp. 67-71, 1 fig.

Results are given of Izod impact, hardness, and tensile tests of chromium-nickel steel of S.A.E. 3250 type with varying nickel and carbon content; higher carbon reduces resistance to impact without production of increased hardness; tempering to 300 degrees Fahr. increases impact resistance without materially affecting hardness but best use of this type of steel is with 550-degrees Fahr. temper.

COMBUSTION CONTROL

Combustion Control Formulas, E. A. Uehling. *Power*, vol. 68, no. 1, July 3, 1928, pp. 29-30.

Author's answer to G. B. Randall's criticism in May 15 issue of this journal, of his articles published in earlier issues.

CUPOLA PRACTICE

The Cupola Furnace, J. E. Hurst. *Iron and Steel Industry (Lond.)*, vol. 1, nos. 5, 6 and 7, Feb., Mar. and Apr. 1928. pp. 147-150, 171-180 and 219-221, 10 figs.

Feb.: Principles and heat inefficiency of cupola; reactions involved in cupola practice; signification of coke reactivity; Piwowarsky's determinations. Mar.: Summary of thermal efficiencies; quantity, velocity and pressure of air supply. Apr.: Critical quantity of air; relation of air to coke ratios; blast pressure; tuyere area; cupola temperatures attained.

CUPOLAS

CONTROL. Cupola Control by Auxiliary Tuyeres. *Engineering (Lond.)*, vol. 125, no. 3257, June 15, 1928, p. 744, 3 figs.

Improved efficiency of cupolas resulting from Poumay system of auxiliary tuyeres for control of combustion in them; system aims at producing carbon monoxide under fusion zone and in completing combustion of this gas inside charge itself so that discharged gases consist almost wholly of carbon dioxide.

FUEL ECONOMY. Fuel Economy in Cupola Practice, Y. Fugo and F. C. Thompson. *Foundry Trade Jl. (Lond.)*, vol. 38, no. 616, June 7, 1928, pp. 405-406, 6 figs.

Three points have been investigated; (1) question as to whether it is possible to increase appreciably rate of reaction by addition of such cheap materials as could be applied in cupola; (2) effect of nature of coke; (3) determination of temperature below which it is unnecessary to cool ascending gases to obtain practical maximum yield of carbon dioxide.

DIES, COLD HEADING

HARDENING. Hardening Cold Heading Dies, L. S. Cope. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 1, July 1928, pp. 51-60, 11 figs.

Author describes quenching apparatus which has been successfully used to quench die so that portion around hole will be hard to withstand wear and remainder of die will be soft enough to withstand shock produced by cold heading; pair of tongs is also described by which header hammers may be quenched so that ends only will be hardened.

ELECTRIC FURNACES

ANNEALING. Electric Annealing of Brass Shows Good Economies, R. M. Keeney. *Elect. World,* vol. 91, no. 25, June 23, 1928, p. 1349.

Recent experience in electric brass annealing shows advances in economy by use of selective load control. Abstract of paper read before Am. Electrochem. Soc., previously annotated.

ANNEALING. Century Electrically Anneals Lamination Sheets. *Elec. World,* vol. 91, no. 24, June 16, 1928, pp. 1301-1302, 1 fig.

To secure more accurate and uniform heat treating of electric sheets used in construction of its products Century Electric Co. has installed in its plant in St. Louis elevator-type electric furnace for annealing lamination iron.

ANNEALING. Electric Annealing of Nonferrous Metals, R. M. Keeney. *Heat Treating and Forging,* vol. 14, no. 6, June 1928, pp. 630-632.

Problem of economies in heating covering heat treatments of brass, copper and nickel-silver products; rolling-mill operations a possibility. Abstract of paper presented before Am. Electro-Chem. Soc.

APPLICATIONS. Some New Applications of Electric Furnaces, A. N. Otis. *Am. Metal Market,,* vol. 35, no. 111, June 12, 1928,, pp. 6-8 and 23, 9 figs.

Work now being done with newer types of equipment; developments in use of electric furnaces, with atmospheres of protective gas, for copper-brazing steel parts together; furnace of elevator type used for annealing sheet steel and punchings for motors and generators; use in nitriding process for case hardening; use of electric heating for processes considered unusual.

FOUNDRY. New Products from an Old Iron Foundry. *Iron Age,* vol. 122, no. 2, July 12, 1928, pp. 78-80, 5 figs.

Modern equipment transforms Chicago plant for American Manganese Steel Co., so that electric manganese steel castings can be made; sand-handling and annealing-furnace features; ball and roller bearings used throughout electrode-operating gear mechanism; electrodes are counterbalanced; annealing furnace has reducing atmosphere.

FOUNDRY. The Electric Furnace in Making Cast Iron. *Heat Treating and Forging,* vol. 14, no. 6, June 1928, p. 648.

Cheap grades of scrap may be used in making synthetic cast iron of superior quality in any desired composition; product is of high strength, toughness and easily machined; investigation involved year's successful operation of jobbing foundry; in electric furnace superior iron, having about twice strength of ordinary cupola iron, can be made; total cost of iron in ladle would be $28 per ton.

HEAT TREATING. The Heat Treatment of Aluminum Alloy Castings and Forgings in the Electric Furnace. *Metal Industry (Lond.),* vol. 32, no. 25, June 22, 1928, pp. 615-616, 2 figs.

With advent of electric furnace for heat treatment many avoidable expenses and difficulties disappear, and such a furnace is practically foolproof and can be operated by unskilled labor; control of temperature is entirely automatic, and after instrument for indicating and controlling temperature has been set, it is not possible in any way to overheat material being treated; cost of running.

HEAT TREATING. Electric Heat Treatment Aids Shovel Manufacturer, W. G. Davies, Jr. *Elec. World,* vol. 92, no. 2, July 14, 1928, p. 74, 1 fig.

At plant of American Manufacturing Co. in Chattanooga one shovel per minute is heat treated at 1500 degrees Fahr. in 30-kw. electric furnace and company is planning to expand this service to heat treat all shovels which it makes.

HEAT TREATING. Steel Castings Heat Treated in Electric Furnace, A. W. Lorenz. *Fuels and Furnaces,* vol. 6, no. 7, July 1928, pp. 923-926 and 950, 8 figs.

Heat treating unit consisting of four box-type electric furnaces equipped with unique charging machine and one car-type furnace, with total capacity of 500 tons per month, used in heat treatment of miscellaneous steel castings; physical properties of castings greatly improved by quenching treatment.

HEAT TREATING, RECUPERATIVE. Normalizing Gear Blanks in the Recuperative Electric Furnace, A. H. Vaughan. *Heat Treating and Forging,* vol. 14, no. 6, June 1928, pp. 599-600, 1 fig.

Return recuperative normalizing furnace; similar to other recuperative furnaces used for variety of work, including carburizing and annealing; furnace is automatic in every detail; capable of normalizing gear blanks at extremely low rate of power consumption on account of recuperative feature.

HIGH FREQUENCY. Valve-Maintained High Frequency Induction Furnace and Some Notes on Performance of Induction Furnaces, G. E. Bell. *Phys. Soc.—Proc. (Lond.),* vol. 40, part 4, June 15, 1928, pp. 193-205, 10 figs.

In part 1, electrical design is given of tube-operated furnace, together with some details of its performance; in part 2, theory of behavior of induction furnaces in general is developed and some experimental results supporting theory are given.

HIGH FREQUENCY. Melting Sterling Silver in High-Frequency Induction Furnaces, R. H. Leach. *Metal Industry (Lond.),* vol. 32, no. 25, June 22, 1928, p. 617.

Abstract of paper read at spring meeting of American Electro-chemical Soc., previously annotated.

HIGH FREQUENCY. Small High Frequency Induction Furnaces. *Metallurgist (Supp. to Engineer, Lond.),* June 29, 1928, p. 83.

Reference is made to furnace described by J. R. Cain and A. A. Peterson, (Jl. of Am. Electro-chem. Soc., 1925, vol. 48, p. 139) in which inductor coil and supports as well as charge, crucible, lagging, etc., were all contained within evacuated bell jar; and also to a furnace inside a bell jar, developed by E. W. Fell (Archiv fuer das Eisenhuettenwesen, Apr. 1928) for preparation of iron and steel meltings of 1 kg.

HIGH FREQUENCY. High Frequency Induction Furnaces (Zur Kenntnis des Hochfrequenz-Induktionsofens), F. Wever and G. Hindrichs. *Mitteilungen aus dem Kaiser-*

Wilhelm-Institut fuer Eisenforschung (Duesseldorf), vol. 9, no. 21, 1927, pp. 319-337, 21 figs.

Contribution to metallurgy of ironless induction furnaces; new furnace types; production of alloyed and unalloyed steels; tests with 100 kw. furnace.

MELTING. Electric Melting, H. S. Primrose. *Iron and Steel Industry (Lond.),* vol. 1, no. 5, Feb. 1928, p. 163.

Heroult furnace for ordinary and alloy steels, as well as cast iron; Ajax-Wyatt, for melting brass; Ajax-Northrup, for special alloy steels, high copper alloys, and metals of high melting point; melting nonferrous scrap.

RESISTANCE. Electric Resistance Type Furnaces, A. Pfau, Jr. *Heat Treating and Forging,* vol. 14, no. 6, June 1928, pp. 666-668.

Development of heating element suitable for production of high temperatures in electric furnace is reviewed and its applications described. Abstract of paper presented before Am. Soc. Steel Treating.

RESISTANT. Carbon Resistor Furnaces for Laboratory Use, H. C. Kremers and L. F. Yntema. *Indus. and Eng. Chem.,* vol. 20, no. 7, July 1928, pp. 770-771, 2 figs.

Description of furnace which has advantages of low initial cost, high temperatures, ease of operation and replacement of heating unit; several have been constructed in laboratory at University of Illinois and are giving satisfaction under varying uses. Presented before Am. Soc. Chem.

STEEL TEMPERING. The "Homo" Method of Tempering Steel. *Iron and Coal Trades Rev. (Lond.),* vol. 116, no. 3144, June 1, 1928, p. 832, 2 figs.

Life of Cutting Tool, assuming suitable steel is employed, is governed entirely by correct tempering; essential that correct tempering conditions may be repeated with absolute accuracy; application of heat under absolute and sensitive control; "Homo" electric furnace illustrated and described.

THEORY. The Coreless Type Induction Furnace, N. R. Stansel and E. F. Northrup. *Heat Treating and Forging,* vol. 14, no. 6, June 1928, pp. 663-665 and 668, 4 figs.

Principles involved in energy transfer in heating charge; part played by frequency in attaining high temperatures and its relation in allowable heat loss; energy absorption and heat loss; varieties of charge; magnetic and nonmagnetic charges. (To be continued.) Abstract of paper from General Elec. Rev.

ELECTRIC OVENS

Electric Carbon Steel Drawing Oven Uses Forced Air Convection, F. E. Finlayson. Iron Trade Rev., vol. 82, no. 26, June 28, 1928, pp. 1667-1669, 6 figs.

New electrically heated air-drawing oven developed by General Electric Co.; heating units well insulated; fan decreases power consumption.

FORGINGS, STEEL

HEAT TREATMENT. Mass Effort in the Heat Treatment of Large Forgings, J. A. Jones. *Metallurgist (Supp. to Engineer, Lond.),* June 29, 1928, pp. 86-90, 14 figs.

Data given illustrate fact that lack of uniformity after treatment is greatest when rate of cooling imposed by mass of material approximates to critical rate of cooling for hardening; they show unsuitability of nickel steel for large forgings and important effect of molybdenum in suppressing mass effect in large masses of nickel-chromium-molybdenum steel.

FURNACES

ANNEALING, GAS FIRED. An Annealing Furnace Built into the Conveyor Line. *Am. Mech.,* vol. 68, no. 26, June 28, 1928, pp. 1050-1051, 2 figs.

New continuous gas-fired annealing furnace installed by Mullins Mfg. Co. to solve problem of annealing steel and copper washing-machine tubs between draws; furnace is based on counterflow principle; performance data.

HEATING—BLAST-FURNACE-GAS FIRED. Thermotechnical Investigations of Modern Morgan Heating Furnace, of Siemens Type, Fired with Blast-Furnace Gas (Waermewirtschaftliche Betriebserforschung eines neuzeitlichen mit Hochofengas gefeuerten Morgan-Waermofens, Bauart Simens), M. Steffes. *Stahl u. Eisen (Duesseldorf),* vol. 48, no. 22, May 31, 1928, pp. 718-721, 14 figs.

Brief description of continuous furnace with Siemens regenerative firing, and account of tests; results obtained with cold charge; critical evaluation of results.

HEATING—BLAST-FURNACE-GAS FIRING. Blast-Furnace-Gas Heating Furnaces for Rolling Mills (Mit Hochofengas beheizte Waermoefen fuer Walzwerke), J. Meiser. *Stahl u. Eisen (Duesseldorf),* vol. 48, no. 25, June 21, 1928, pp. 822-823.

Abstract of Report No. 39, of Rolling-Mill Committee of Verein deutscher Eisenhuettenleute, abstracted from Archiv fuer das Eisenhuettenwesen, Apr. 1928, previously annotated.

HEAT TREATING. Furnace for Treating Stainless Cutlery, G. J. Comstock. *Heat Treating and Forging,* vol. 14, no. 6, June 1928, pp. 661-662, 1 fig.

Development of heating furnace for use in heat treatment of stainless steel cutlery is described; special problems involved in bringing out stainless properties.

HEAT TREATING—CONVEYOR PARTS. Modern Conveyor Parts Heat Treated, J. B. Nealy. *Heat Treating and Forging,* vol. 14, no. 6, June 1928, pp. 669-671, 3 figs.

Gas-fired furnaces used in production and heat treatment of conveyor chain are described in relation to efficiency in production; furnaces in forge shop; furnaces in heat treating department.

HEAT TREATING, GAS FIRED. Company Designs Successful Belt Type, Gas Fired Furnace for Heat Treating Its Product, H. Stark. *Am. Gas Jl.,* vol. 128, no. 6, June 1928, pp. 33-35, 2 figs.

Continuous metal ribbon utilized to carry work through heating zones and automatically discharge it into quenching medium; furnace successful and company now has seven in daily operation, with contemplated additions; study of fuel conditions; ease of utilization, cleanliness, maintenance and other desired factors, balanced against cost per pound of delivered heat treated work, led to adoption of gas as fuel; underfired heating method; low fuel consumption; labor costs low.

INDUSTRIAL. Comparison of Electric Furnaces with Oil and Coal-Fired Furnaces (Comparacion de los hornos electricos con los hornos de aceite y carbon), K. W. Borck, *Revista Minera (Madrid)*, vol. 79, no. 3121, May 24, 1928, pp. 245-247.

Oil furnace has all disadvantages of short-flame furnaces, notably products of combustion coming in contact with furnace charge and influencing chemical composition; electric furnaces cost more and operating expense is usually greater, but are often more economical because of easy control, cleanliness and purity of product.

METALLURGICAL — OIL FIRING. Oil Fuel as Applied to Metallurgical Works. *Metal Industry (Lond.)*, vol. 32, no. 23, June 8, 1928, pp. 572-573.

Advantages of oil over solid fuels in industrial furnaces may be summed up as follows: increase of output, economy of fuel, less material wastage, much higher temperatures obtained in shorter periods, temperature under instant control, saving in furnace attendance and less floor space.

HARDNESS TESTING MACHINES

The Herbert Cloudburst Hardness Testing Machine, E. G. Herbert. *Engineering (Lond.)*, vol. 126, no. 3260, July 6, 1928, pp. 28-29, 5 figs.

Details of Cloudburst testing machine at works at Manchester, of B. and S. Massey; consists essentially of rubber-lined chamber in which work to be tested is placed, tube down which balls fall on to work, and provision for raising supply of balls to required height.

A new Hardness Testing Machine. *Engineer (Lond.)*, vol. 145, no. 3780, June 22, 1928, pp. 696-697, 3 figs.

Details of simple form of machine for carrying out tests on number of articles simultaneously; it is patented invention of E. G. Herbert; principle of operation of "Cloudburst" machine is to "rain down" vast number of small hard steel balls from height adjustable to hardness requirements of particular case upon whole surface under test.

HARDNESS TESTS

BRINELL. A Brinell-Test Investigation, A. L. Norbury and T. Samuel. *Iron and Coal Trades Rev. (Lond.)*, vol. 116, no. 3145, June 8, 1928, p. 860.

Research of "sinking-in" or "piling-up" and "flattening" and "elastic recovery" of 10-mm. ball Brinell impressions on number of materials; sceleroscope, pendulum, and 90-deg. cone tests also made on same materials; correlation with Brinell test discussed; 40 annealed and tempered carbon and chromium steels, hardness 100 to 700 Brinell, were tested. Abstract of paper presented before Iron and Steel Inst.

HIGH SPEED STEEL

MAGNETIC ANALYSIS. The Incremental Permeability Method for the Magnetic Analysis of High Speed Steel, W. B. Kouwenhoven and J. D. Tebo. *Am. Soc. Testing Matls.—Preprint*, no. 31, for mtg. June 25, 1928, 19 pp., 11 figs.

Describes new method of magnetic analysis which authors call incremental-permeability method; it uses two magnetomotive forces simultaneously, and change in induction produced by superimposed or incremental magnetomotive force in specimen is measured; this force may be produced by d. c. or a. c. current; magnetic properties of high speed tungsten steel bars were investigated and data were obtained which makes it possible to differentiate between heat treatments received by specimens.

IMPACT TESTING

NOTCHED BAR. What Short Standard Notched-Bar Test? (Welche kleine Kerbschlag-Normalprobe?) F. P. Fischer. *Kruppsche Monatshefte (Essen)*, vol. 9, Apr. 1928, pp. 53-60, 32 figs. on supp. sheets.

Compares, theoretically and experimentally, notch impact tests and concludes that Mesnager test, which has already been adopted by France, Belgium, Italy and Czechoslovakia, should be adopted internationally.

INGOT MOLDS

WATER COOLED. Ingot Molds With Water Cooled Walls (Les lingotières refroidies extérieurements par l'eau). *Technique Moderne (Paris)*, vol. 20, no. 11, June 1, 1928, p. 404, 3 figs.

Shows advantages of quick cooling of copper and brass ingots by water applied around mold.

IRON

INCLUSIONS. Inclusions in Iron, C. R. Wohrman. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 1, July 1928, pp. 81-126, 39 figs.

Photomicrographic study; outline of inclusion problem and of author's work; preparation of artificially known inclusions; polishing for inclusions; microscopic examination; oxide inclusions (and silicates); 2-page bibliography.

NITROGEN CONTENT. Nitrogen in Iron (L'azote dans le fer technique), V. and N. Svetchnikoff. *Revue de Métallurgie (Paris)*, vol. 25, no. 4, Apr. 1928, pp. 212-221, 13 figs.

Examples from practice; analytical method of nitrogen determination; nitrogen liquefaction. (To be continued.) Translated from Russian.

IRON ALLOYS

FERRITE MICROSTRUCTURE. The Micro-Structure of Ferrite. *Metallurgist (Supp. to Engineer, Lond.)*, June 29, 1928, pp. 94-95.

Paper deals with investigation of various markings which are sometimes found in ferrite. Abstracted from U. S. Bur. of Standards—Sci. Paper, no. 571, previously annotated.

NICKEL. The Influence of Nickel on Iron-Carbon-Silicon Alloys containing Phosphorus, A. B. Everest and D. Hanson. *Iron and Coal Trades Rev. (Lond.)*, vol. 116, no. 3145, June 8, 1928, pp. 862-866, 20 figs.

Refers to paper on earlier investigations; recent experiments involve phosphorus; phosphorus increases hardness, tendency to chill, and difficulty of machining; more nickel required to produce given result in presence of high phosphorus, where there is tendency

to chill, than would be required in presence of lower phosphorus. Paper read before Iron and Steel Inst. previously annotated.

NICKEL. The Influence of Nickel and Silicon on an Iron-Carbon Alloy, A. B. Everest, T. H. Turner and D. Hanson. *Iron and Steel Industry (Lond.),* vol. 1, no. 6, Mar. 1928, p. 194.

Account of preliminary work on effect of nickel on simple iron-carbon-silicon alloys, over ranges of nickel between 0 and 40 per cent, and of silicon between 0 and 3.6 per cent. Abstract of paper read before Iron and Steel Inst.

IRON AND STEEL

CORROSION. Corrosion of Iron and Steel, W. B. Lewis and G. S. Irving. *Iron and Steel Industry (Lond.),* vol. 1, no. 6, Mar. 1928, pp. 185-186.

Corrosion of iron and steel in general and more particularly corrosion in marine boilers; acid theory; older electro-chemical theory; colloidal theory; differential-aeration corrosion in steam boilers; two main types of corrosion; water level corrosion; importance of keeping boilers free from scale; Condensed from paper read before Inst. Mar. Engrs.

CORROSION. Resistance of Over-Stressed Wrought Iron and Carbon Steels to Salt-Water Corrosion, J. N. Friend. *Iron and Coal Trades Rev. (Lond.),* vol. 116, no. 3146, June 15, 1928, p. 902.

Brief abstract of paper read before Iron and Steel Inst., previously annotated.

PROTECTIVE COATINGS. The Protection of Iron by Parkerization (La proteccion del Ferro por la parkerizacion). *Boletin de la Sociedad de Fomento Fabril (Santiago, Chile),* vol. 45, no. 4, Apr. 1928, p. 223.

Parkerization consists in coating iron with film of phosphates that protects against corrosion; parts cleaned and freed of rust particles, then dipped in boiling acid bath containing 3 to 4 per cent phosphates of iron and manganese; deposition of films begins after half hour; process suitable only for ferrous metals and alloys.

TESTING. Creep in Ferrous Materials, H. J. Tapsell and W. J. Clenshaw. *Iron and Steel Industry (Lond.),* vol. 1, no. 5, Feb. 1928, pp. 164-165, 1 fig.

Discussion of report on properties of materials at high temperatures, issued by Department of Scientific and Industrial Research; results of tensile, creep, torsion and hardness tests on Armco iron and 0.17 per cent carbon steel.

IRON AND STEEL METALLURGY

Metallurgical Theories for the Practical Iron and Steel Man, C. H. Plant. *Iron and Steel Industry (Lond.),* vol. 1, nos. 4 and 5, Jan. and Feb., 1928, pp. 113-114 and 159-160, 3 figs.

Jan.: Properties of iron and influence of carbon on hardness, strength and shrinkage of cast iron; effect of chilling. Feb.: Influence of various impurities in cast iron; cumulative effect of impurities; interaction of sulphur, phosphorus and manganese; segregation; checking, softness, workability, and strength; casting temperature of cast iron. (Continuation of serial.)

Metallurgical Theories for the Practical Iron and Steel Man, C. H. Plant. *Iron and Steel Industry,* vol. 1, nos. 6 and 8, Mar. and May 1928, pp. 193-194 and 250-252, 3 figs.

Mar.: Alloy steels, and influence of additional elements added deliberately in order to develop certain desired properties; ternary steels; irreversible transformations. May: Information respecting nickel steels afforded by their equilibrium diagram; manganese, chromium, and silicon steel discussed; influence of rate of cooling; self-hardening steel; discovery of high speed steels. (Concluded.)

Iron and Steel Metallurgy (Eisenhuettenwesen), Diepschlag. *V.D.I. Zeit. (Berlin),* vol. 72, no. 23, June 9, 1928, p. 785.

Annual review of engineering progress in construction and operation of coking plants, blast furnaces, steel plants, and rolling mills.

IRON CASTINGS, GRAY

The Production of Some Important Grey-Iron Castings, E. Longden. *Foundry Trade Jl. (Lond.),* vol. 38, no. 616, June 7, 1928, p. 411.

Discussion of paper presented before Sheffield Branch of Inst. Brit. Foundrymen, including brief abstract of paper; correct gating of castings; effect of spray pouring; discussion dealt with pencil runners or hard spots; internal chills and cracking; hydraulic ram castings; author's reply.

IRON-SILICON ALLOYS

Constitution of the Iron-Silicon Alloys, M. G. Corson. *Heat Treating and Forging,* vol. 14, no. 6, June 1928, pp. 634-638 and 647, 18 figs.

Physical properties and corrosion-resistant qualities discussed; influence of carbon and of different metallic and non-metallic additions shown in relation to strength and microstructure; physical properties of iron-silicon alloys. (Continuation of serial.) Abstract of paper presented before Am. Inst. of Min. and Met. Engrs.

MAGNETS, PERMANENT

MAGNETIZATION. A Simple Method for Magnetizing of Permanent Magnets (Ein einfaches Verfahren zum Magnetisieren von permanenten Magneten), E. Schulze. *Elektrotechnische Zeit. (Berlin),* vol. 49, no. 26, June 28, 1928, pp. 969-974, 16 figs.

Describes patented Beckmann method (German Patent no. 241,705) of magnetizing brake magnets and similar permanent magnets by means of induction current impulse generated by closing or interrupting of current of d. c. transformer; theory and experimental tests of processes; economy and practical efficiency of method.

MALLEABLE CASTINGS

Malleable Castings, W. T. Evans and A. E. Peace. *Foundry Trade Jl. (Lond.),* vol. 38, nos. 617 and 618, June 14 and 21, 1928, pp. 423-426 and 453-457, 21 figs.

Authors endeavor to convince engineers and users of malleable castings that reliable product from black-heart and white-heart varieties is being produced by application of correct methods; air-furnace melting for black heart; conditions influencing life of refractories; melting for white heart; use

of refined irons; common defects; molding, feeding, annealing. (To be continued.)

Carbon-Silicon Ratio Determines Physical Qualities of Malleable, L. E. Gilmore. *Foundry,* vol. 56, no. 13, July 1, 1928, pp. 529-531, 1 fig.

Usual six chemical elements present in metal, namely, iron, phosphorus, manganese, sulphur, carbon and silicon; three factors that determine whether or not carbon in casting will be combined entirely or partly free; combination of greatest tensile strength and ductility for malleable castings is obtained with low carbon and high silicon.

Malleable Castings, W. T. Evans and A. E. Peace. *Foundry Trade Jl. (Lond.),* vol. 38, no. 619, June 28, 1928, pp. 478-481, 13 figs.

Discussion of following factors: question of even sections; pyrometry; effect of common elements on black heart and on white heart malleable; considerations of costs. (Concluded.)

SHRINKAGE. The Shrinkage and Expansion Due to Annealing of Malleable Castings (Ueber Schwindung und Gluehausdehnung beim Temperguss), F. Henfling. *Giesserei (Duesseldorf),* vol. 15, no. 23, June 8, 1928, pp. 534-541, 17 figs.

Based on practical tests, author discusses influence of silicon, manganese, temperature of molten metal, thickness of rod, etc., on shrinkage and expansion; recommends change in shrinkage-measuring apparatus.

MANGANESE STEEL

MACHINING. Progress in Machining Manganese Steel, A. S. Martin. *Machy. (N. Y.),* vol. 34, no. 11, July 1928, pp. 862-863, 3 figs.

Examples of what is now being accomplished in way of machining cast and rolled manganese steel; proper tool angles, feeds, and speeds determined by experiments; shape of drill points for manganese steel; cutting keyways; shaping, planing and boring operations. (Continuation of serial.)

PROPERTIES. Medium Carbon Pearlitic Manganese Steels, J. Strauss. *Am. Soc. Steel Treating—Trans.,* vol. 14, no. 1, July 1928, pp. 1-25 and (discussion) 25-26, 7 figs.

Discussion of metallurgical and mechanical characteristics of steel of 0.30 to 0.50 per cent carbon and 1.00 to 2.00 per cent manganese; both wrought and cast forms are considered in both light and heavy sections; author points out similarity of these steels to other structural alloy combinations, limitations of heavy sections and of low tempering temperatures, and advantages in respect to cutting qualities, resistance to corrosion, and strength at moderate temperatures. Bibliography.

METALLOGRAPHY

Metallography Simplified for Practical Use in Shop, E. Preuss, G. Berndt and M. v. Schwarz. *Iron Trade Rev.,* vol. 83, no. 2, July 12, 1928, pp. 78-80, 12 figs.

Testing steel by etching; pipes and pores occur in every steel solidified from liquid state; pipes, blowholes, laps, and rolling cracks can be recognized on roughly worked surface without necessity for etching; to see quantity and extent of phosphorus segregations, etching with copper-ammonium-chloride is recommended. (Continuation of serial.)

METALS CUTTING, MACHINE

Machine Cutting in Railroad Shops, W. Wiggin. *Am. Welding Soc. Jl.,* vol. 7, no. 6, June 1928, pp. 59-61, 5 figs.

Cost of cutting is low and speed of cutting high due to fact that nearly all responsible pieces are preheated before being cut; preheating before cutting and annealing after cutting is finished, is modern way of cutting responsible pieces which has eliminated all former objections against machine cutting.

METALS

DEFORMATION. Permanent Deformations of Repeatedly Heated and Cooled (Ueber die bleibenden Formaenderungen wiederholt erhitzter und abgekuehlter Koerper), F. Berger. *V. D. I. Zeit. (Berlin),* vol. 72, no. 26, June 30, 1928, pp. 921-926, 22 figs.

Discusses elongation due to heating as irreversible reaction; growth of iron, brass and other metals; effect of rate of cooling on surface stresses; example of steel specimen heated 374 times; changing of temperature field in case of rapid cooling; temperature phenomena at singular points.

FLOW. Stresses Causing Flow (Zur Ableitung einer Fliessbedingung), G. Sachs. *V. D. I. Zeit. (Berlin),* vol. 72, no. 22, June 2, 1928, pp. 734-736, 4 figs.

Report from Kaiser Wilhelm Institute of Metals, in Berlin-Dahlem, on tentative theory accounting for permanent deformations and plastic flow of aggregations of crystals on basis of properties of single crystals; summary of experimental studies of effect of tensile and torsional stresses on flow of copper, nickel and iron.

FLOW. Effect of Average Principal Stress on the Flow of Metal (Der Einfluss der mittleren Hauptspannung auf das Fliessen der Metalle), W. Lode. *V. D. I. Zeit. (Berlin),* vol. 72, no. 22, June 2, 1928, p. 733.

Report of study made at Institute of Applied Mechanics of University of Goettingen; tests were made on thin-walled tubes. Abstract from No. 303 of Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, previously annotated.

PLASTIC DEFORMATION. The Exposure of Internal Plastic Deformations in Metals (Zur Sichtbarmachung plastischer Verformungen im Inneren eines Werkstueckes), G. Tammann and M. Starumanis. *Zeit. fuer Metallkunde (Berlin),* vol. 20, no. 5, May 1928, pp. 184-185, 4 figs.

Experiments were made with coins of silver-copper, alloy, nickel, iron and copper; after polishing off deformed surface of coin, it is possible by means of etching, to render visible change in crystallite orientation, brought about by stamping, especially when metal is in hardened state.

SEASON CRACKING. Season Cracking—A Practical Note, A. L. Walker. *Machy. (Lond.),* vol. 32, no. 819, June 21, 1928, pp. 365-366.

Practical understanding of causes and remedies pertaining to season or stress cracking of metals; season cracking of alloys is

result of stress accumulation; shown by microscope that season cracking is caused by separation of whole crystals; chemical methods serving to show whether metals are liable to season cracking; methods of prevention.

TESTING. The Mechanical Testing of Metals, T. F. Russell. *Metal Industry (Lond.)*, vol. 32, no. 22, June 1, 1928, pp. 537-541, 11 figs.
Tensile testing machines and extensometers. (Continuation of serial.)

TESTING. A. S. T. M. Holds Annual Meeting. *Iron Trade Rev.*, vol. 83, no. 1, July 5, 1928, pp. 15-18, 22 and 50.
Review of meeting of Am. Soc. for Testing Matls.; study of centrifugal pipe in comparison with sand-cast pipe; knowledge of wear resistance of metals sought; few marked changes suggested in report of committee on steel; magnetic testing; wider use of A. S. T. M. specifications urged.

TESTING. Magnetic Testing Featured at Testing Materials Meeting. *Am. Mach.*, vol. 69, no. 1, July 5, 1928, p. 36b.
Review of meeting of Am. Soc. for Testing Materials; papers presented by H. Styri on endurance of high speed cut-off tools in relation to magnetic and other measurements, by J. B. Kommers on results of his recent tests on cast iron, and by W. B. Kouwenhoven and J. D. Tebo describing new method of magnetic analysis.

TESTING. Metal Studies by Testing Society. *Iron Age*, vol. 122, no. 1, July 5, 1928, pp. 28-30 and 61.
Review of meeting of Am. Soc. for Testing Materials; extensive investigations under way on corrosion resistance of sheets, and properties of steel castings and die castings.

X-RAY ANALYSIS. Applied X-Rays in the Metal Industry, H. R. Isenburger. *Metal Industry (N. Y.)*, vol. 26, no. 6, June 1928, pp. 271-272, 5 figs.
Inspection of rough structure of metals by means of X-rays serves to discover slags, shrinkage, blowholes and like in unfinished, semi, and manufactured products; method is based upon capacity of X-rays to penetrate materials; most important practical application of X-rays in metal-working industry are enumerated.

X-RAY ANALYSIS. X-Rays in Industry, H. R. Isenburger. *Instruments*, vol. 1, no. 6, June 1928, pp. 271-273, 6 figs.
Discussion of penetrating power of X-rays for examination of wrought or semifinished metals; method of analysis explained; exposure times for bronze, iron and steel, and aluminum for varying voltages; examples of applications and importance of methods described.

NONFERROUS METALS

RESEARCH. Nonferrous Metals Research. *Gas Jl. (Lond.)*, vol. 182, no. 3395, June 13, 1928, p. 726.
Influence of impurities on copper; improving soundness of brass castings; lead alloys for cable sheathing; exploration of alloys for high-temperature service; locomotive-firebox stays; atmospheric corrosion; die-casting alloys; new alloys for condenser tubes; new section founded to assist members to apply in their works new products and improvements of processes arrived at from researches. Brief abstract of report of Brit. Nonferrous Metals Research Assn.

OPEN-HEARTH FURNACES

LINING. Fettling Machine for Open-Hearth Furnaces. *Indus. Mgmt. (Lond.)*, vol. 15, no. 6, June 1928, pp. 196-197, 2 figs.
Description of machine for replacing lining of furnace entirely by mechanical means; material is fed on belt moving at very high velocity and is thrown into furnaces in much same way as if by shovel; will throw approximately one ton of dolomite or sand per minute under perfect control and will completely line 50-ton furnace in from 10 to 15 minutes; built by Blaw-Knox Co., of Pittsburgh, Pa.

REGENERATOR INSULATION. The Insulation of Open-Hearth Furnace Regenerators, L. B. McMillan. *Iron and Steel Engr.*, vol. 5, no. 6, June 1928, pp. 257-262, 9 figs.
Calls attention to highly satisfactory and very practical results which are being accomplished on actual installations; advantageous results attained through use of insulation on checker chambers; heat losses from walls and roofs; value of savings effected by insulation; savings expressed as percentages of total fuel cost; insulation of new and old checker chambers; conclusions.

REGENERATORS. The Kuehn Regenerator System (Das Kuehnsche Regeneratorsystem), Thaler. *Feuerungstechnik (Leipzig)*, vol. 16, no. 11, June 1, 1928, pp. 123-125, 3 figs.
Author points out disadvantages of present regenerative furnace; comparison between Cowper and open-hearth furnace chamber; description of Kuehn open-hearth furnace chamber and its operation; advantages of Kuehn regenerator.

RAILS

CHROMIUM STEEL. Chromium Steel Rails, T. Swiden and P. H. Johnson. *Iron and Steel Can. (Gardenvale, Que.)*, vol. 11, no. 6, June 1928, pp. 174-176.
Influence of reheating and cooling in air; influence of simple heat treatment; typical carbon steel rails; service reports on chromium steel rails; chromium steel fishplates. Abstract of paper read before Iron and Steel Inst.

METALLURGY. Notes on Inverse Segregation Observed in Certain Rails (Nate sur la segregation inversée observée dans certains rails), A. Portevin. *Revue Universelle des Mines (Liege)*, vol. 18, no. 5, June 1, 1928, pp. 205-207, 3 figs.
Metallurgy of segregation and micrographic examination of rail sections.

PROPERTIES, STEEL. Endurance and Other Properties of Rail Steel as Affected by Type of Ingot Produced, J. R. Freeman, Jr., R. L. Dowdell and W. J. Berry. *Iron and Steel World*, vol. 2, no. 7, July 1928, pp. 337-338 and 342.
Results of series of tests on rail steel carried out by U. S. Bureau of Standards with particular reference to their resistance to repeated stress; endurance limit of steel from 100-lb. rails was found to vary from minimum of approximately 41,000 lb. per sq. in. to maximum of approximately 59,000 lb. per sq. in., and endurance ratio

from 37 to 44 per cent; in general, rails rolled from sink-head ingots had higher endurance limits.

STEEL RESEARCH. Fatigue Resistance of Rail Steel, J. R. Freeman, Jr. *Iron Age,* vol. 121, no. 25, June 21, 1928, pp. 1743-1745, 3 figs.

Discussion of test data secured from Bureau of Standards investigations of comparative properties of rails made from rising steel in standard big-end-down ingot molds and rails from fully piping (killed), steel made in big-end-up sinkhead ingot endurance ranges from 46,000 to 59,000 lb. per sq. in.; rail steel killed with aluminum can be poured free from pipe and excessive segregation in sink-head molds of Gathmann type.

TESTING. Endurance and Other Properties of Rail Steel Investigation. *Eng. News-Rec.,* vol. 101, no. 1, July 5, 1928, p. 7.

Results of cooperative investigation by Bureau of Standards with manufacturers Rail Steel Committee and Joint Committee on Stresses in Track of Am. Ry. Eng. Assn. and Am. Soc. Civil Engrs., on rail failures, with particular reference to transverse-fissure failures.

TRANSVERSE FISSURES. Surface Fissures in Rail Treads, M. Viteaux. *Metallurgist (Supp. to Engineer, Lond.),* June 29, 1928, pp. 91-92, 1 fig.

Account of searching and elaborate study of production of fissures and their effects on mechanical properties of rails made at Neuves Maison works of the Compagnie des Forges de Chatillon. Abstract translated from Revue de Métallurgie, Sept., Oct., Nov., 1927. (To be continued.)

ROLLING MILLS

ELECTRIC DRIVE. Selection of Motors for Main Drives of Merchant, Bar and Rod Mills, C. B. Houston. *Iron and Steel Engr.,* vol. 5, no. 6, June 1928, pp. 218-229, 19 figs.

Description of number of types of mills and their drives; applications which have been made of electric motors to merchant bar and rod mills; shows kind of mill and particular layout may materially effect choice of motor as to type, capacity, speed and method of control.

ELECTRIC DRIVE. The Selection of Main Drive Motors for Strip and Skelp Mills, A. F. Kenyon. *Iron and Steel Engr.,* vol. 5, no. 6, June 1928, pp. 248-255, 20 figs.

Method of calculation of power requirements for individual passes of mill; partial list of main-roll motors on skelp mills; hoop and small strip mills; large strip mills; roller-bearing mills; methods of selecting capacities of driving motors.

ELECTRIC MOTORS. Present Practices in Connection with Motor Driven Rollers, J. C. Dobelbower. *Iron and Steel Engr.,* vol. 5, no. 6, June 1928, pp. 235-236.

Several different designs and applications of roll-out motors.

REPAIR SHOPS, ELECTRIC. Layout of the Electrical Repair Shop, W. A. Beck. *Indus. Eng.,* vol. 86, no. 6, June 1928, pp. 289-293 and 310, 4 figs.

Methods of servicing continuous-process equipment; deals with electric repair-shop practices and facilities provided in general maintenance scheme in first plant of its kind engaged in manufacture of iron sheets on continuous basis; personnel chart shown makes clear organization set-up that is responsible for class of work that is done.

SHEET STEEL INDUSTRY

To Increase Trade Extension Work. *Iron Age,* vol. 121, no. 24, June 14, 1928, pp. 1685 and 1728.

Review of meeting of Flat-Rolled Steel Executives sponsored by National Association of Flat-Rolled Steel Mfgrs.; manufacturers of flat-rolled steel to unite in promoting program of trade extension activities and of market research; low profits and forced production called menace to industry; production must be adjusted to market conditions.

What Sheet Industry Needs to Do, O. H. Cheney. *Iron Age,* vol. 121, no. 24, June 14, 1928, pp. 1682-1683.

Low prices and low earnings of steel trade in general and of sheet and strip steel industry in particular, discussed; sheet industry needs to go into cooperative research and education, as through advertising, and forget fear of excess capacity; establishing one-price policy. Abstract of address before Nat. Assn. of Flat-Rolled Steel Mfrs.

Buyer Talks on Pressed Metal Selling, W. B. Calkins. *Iron Age,* vol. 121, no. 24, June 14, 1928, p. 1697.

Various selling methods, making of prices and other subjects having to do with relations between purchasing department and purveyor of stampings and other products used in manufacture of automobiles are discussed. Abstract of paper presented before Pressed Metal Inst.

SILICON STEEL

Production and Properties of Silicon Steel (Herstellung und Eigenschaften von Siliziumstahl), C. Wallmann. *Stahl u. Eisen (Duesseldorf),* vol. 48, no. 25, June 21, 1928, pp. 817-821 and (discussion) 821-822, 2 figs.

Discussion of peculiarities in melting of silicon steel, its treatment in rolling mill and effect on production costs; influence of deformation in rolling, rolling temperature, and annealing, on strength and elasticity; deals with problem of acceptance test values for silicon steel.

STAINLESS STEEL

Chromium Steels and Stainless Iron. *Machy. (Lond.),* vol. 32, no. 820, June 28, 1928, pp. 418-419.

Properties conveyed by various amounts of chromium in steel and uses of such steels; chromium in steel is hardening agent but does not confer marked hardness in absence of carbon; as chromium content is raised steel becomes progressively stronger and harder and loses ductility to some extent, and corrosion-resisting properties increase; properties of special class of stainless steel known as stainless iron made with carbon content not exceeding 0.1 per cent.

BRAZING AND WELDING. Soldering, Brazing, and Welding Stainless Steels. *Mech. World (Manchester),* vol. 83, no. 2160, May 25, 1928, pp. 377-379.

Brazing stainless steels; blowpipe, dip, and open-fire methods of brazing; in making brazing alloys constituent metals should be commercially pure; brazing fluxes; preparing

joints for brazing; preparing metal for welding; largest consumers of specially ductile varieties are chemical manufacturers; stainless steel employed for turbine blades. (Concluded.)

STAINLESS STEEL PROPERTIES

The A-B-C of Corrosion Resisting Steels, F. R. Palmer. *Chem. and Met. Eng.*, vol. 35, no. 6, June 1928, pp. 364-365.

Critical comment by W. Mitchell on article in March issue of same journal; includes reply by Palmer.

STAINLESS STEEL WELDING

Welding Corrosion Resisting Steel Alloys, W. B. Miller. *Am. Welding Soc.—Jl.*, vol. 7, no. 6, June 1928, pp. 15-23.

Discussion of paper published in May 1928, issue of same journal, previously annotated.

STAINLESS STEELS

X-RAY ANALYSIS. X-Rays and the Constituents of Stainless Steel, E. C. Bain. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 1, July 1928, pp. 27-50, 10 figs.

Author deals with utilization of X-rays in study of fundamental nature of stainless steel; general survey of properties of alloys in which chromium is utilized to develop rustlessness; changes in amounts and conditions of crystalline phases responsible for hardness and rust resistance as developed by variety of quenching tempering operations have been followed by means of X-rays.

STEEL

AUTOMOBILE. British and American Automotive Steels, J. W. Urquhart. *Heat Treating and Forging*, vol. 14, no. 6, June 1928, pp. 610-612.

Features of difference exist in chemical specifications, resulting in less difficult heat Ford methods particularly are cited; range treatments on parts in American practice; of what are regarded in Europe as commercial use carbon steels, as employed by Ford organization, is given; chemical analysis of steels; depth of hardening in automobile work. (To be continued.)

CARBURIZED. On Influence of Occluded Oxygen in Steel upon Carburizing Quality of Steel, K. Inouye. *Kyushu Imperial Univ. College of Eng.—Memoirs (Japan)*, vol. 5, no. 1, Jan. 1928, 69 pp., 49 figs. partly on supp. pp.

Oxygen in steel has very marked influence upon physical and mechanical properties of steel; method of analyzing oxygen; general principle of Oberhoffers process; results of analysis; effect of oxygen content upon carburized structure and also depth of penetration of carbon in carburization.

COLD DRAWING. Contribution to the Study of Cold Drawing of Soft Steel (Contribution a l'étude de l'étriage à froid de l'acier doux), R. Giraud. *Revue de Métallurgie (Paris)*, vol. 25, no. 4, Apr. 1928, pp. 175-194, 44 figs.

Discussion of mechanical properties of steel hardening as result of cold drawing, especially for soft steel. (To be continued.)

CORROSION TESTING. Service Is Best Test of Steel, H. M. Boylston. *Iron Age*, vol. 121, no. 24, June 14, 1928, pp. 1665-1668, 5 figs.

Accelerated and salt spray tests not conclusive; many acid tests for corrosion are misleading; temperature time, strength of solution, agitation and other variables which discredit tests; views of testing engineers; service only authoritative guide.

DUPLEX. Uniformity in Duplex Steel, F. W. Sunblad. *Iron Age*, vol. 121, no. 26, June 28, 1928, pp. 1812-1813.

Manufacture of duplex heat relatively free from gases is rather complicated proposition; each charge contains unstable conditions which influence quality of product; quality product is obtained by controlling temperature of steel bath and fluidity of slag just before molten pig iron is charged.

FATIGUE STRESSES. Fatigue of Mild Steel, W. R. Needham. *Machy. (Lond.)*, vol. 32, no. 820, June 28, 1928, p. 405.

Tests of fatigue limits of construction materials subjected to rapid and continuous reversals of stress are discussed; determining effect of temperature and effect of rate of stress alteration; conclusions given from paper by H. J. Tapsell presented before Iron and Steel Inst.

HEAT TREATMENT—CYANIDING. Cyanide Hardening of Steel, S. Tour. *Fuels and Furnaces*, vol. 6, no. 7, July 1928, pp. 883-892.

Cyanogen-gas process; cyanamide process; depth of penetration; concentration of cyanide in bath; cyanide brittleness; general practice in cyanide hardening.

HEAT TREATMENT—QUENCHING OILS. A New Quenching Oil. *Machy. (Lond.)*, vol. 32, no. 817, June 7, 1928, p. 317.

New quenching oil which, according to test results furnished by Sheffield Testing Works, Ltd., would appear to possess considerable advantages by comparison with majority of quenching oils in use in respect to specific heat, conductivity, viscosity, and volatility; tables of results of tests.

METALLOGRAPHY. A Study of the Structure of Martensite, A Allison. *Heat Treating and Forging*, vol. 14, no. 6, June 1928, pp. 624-626, 10 figs.

Question of angular condition of martensite constituent in hardened steel is discussed and examples are given; effect of angularity of structure on serviceability; high temperature in forging and rolling; examples of angular martensite.

OXYGEN DETERMINATION. Influence of Certain Elements in Iron on Oxygen Determination in Steel According to Hydrogen-Reduction Process (Einfluss einiger Begleitelemente des Eisens auf die Sauerstoffbestimmung im Stahl nach dem Wasserstoffreduktionsverfahren), P. Bardenheuer and C. A. Mueller. *Archiv fuer das Eisenhuettenwesen (Duesseldorf)*, vol. 1, no. 11, May 1928, pp. 707-708 and (discussion) 708-715.

Based on investigation, conclusion is drawn that hydrogen-reduction process is only applicable to steels that are carbon-poor and contain no silicon, aluminum and other metal whose oxides in presence of iron cannot be reduced by hydrogen.

OXYGEN DETERMINATION. Influence of Certain Elements in Iron on Oxygen Determination in Steel According to Hydrogen-Reduction Process (Einfluss einiger Begleitelemente des Eisens auf die Sauerstoffbestimmung im Stahl nach dem Wasserstoffreduk-

tionsverfahren), P. Hardenheuer and C. A. Mueller. *Stahl u. Eisen (Duesseldorf)*, vol. 48, no. 24, June 14, 1928, p. 795.

Brief abstract of report previously annotated from Archiv fuer das Eisenhuettenwesen, May 1928, p. 707.

STRAIN HARDENING. The Strain Hardening of Carbon Steels Under Influence of Deformation in Relation to Temperature, Time and Structure (Ueber die Verfestigung von Kohlenstoffstaehlen bei Verformung in Abhaengigkeit von Temperatur, Zeit und Gefuege), F. Sauerwald, L. Michalsky, R. Kraiczek and G. Neuendorff. *Archiv fuer das Eisenhuettenwesen (Duesseldorf)*, vol. 1, no. 11, May 1928, pp. 717-720, 3 figs.

Results of impact tests; measurement of strain hardening by determination of hardness increase; static tensile tests; establishment of limits between cold and hot deformation. See brief abstract in Stahl u. Eisen (Duesseldorf), vol. 48, no. 23, June 7, 1928, pp. 770-771.

TESTING. The Testing of Steel (Stahlpruefung), R. Schaeger. *Waerme (Berlin)*, vol. 51, nos. 22 and 23, June 2 and 9, 1928, pp. 400-405, and 417-419, 15 figs.

Author reviews most important mechanical test methods, namely: tensile tests, ball pressure tests and notched-bar tests and critically discusses their adaptability to testing of steel; he considers two last named methods of greater importance than tensile test.

TEMPERATURE EFFECT. Fatigue-Resisting Properties of 0.17 per cent Carbon Steel at Different Temperatures and at Different Mean Tensile Stresses, H. J. Tapsell. *Iron and Coal Trades Rev. (Lond.)*, vol. 116, no. 3140, May 4, 1928, pp. 650-651, 4 figs., and discussion in no. 3142, May 18, p. 759.

Little published information relating to fatigue-resisting properties of steel at high temperatures; description of tensile, creep, and fatigue tests undertaken to estimate practical fatigue limits for different temperatures; discussion of results. Abridgment of paper read at Iron and Steel Inst.

UTILIZATION—LOCOMOTIVE FORGINGS. Steels for Locomotive Forgings, E. J. Edwards. *Metallurgist (Supp. to Engineer, Lond.)*, June 29, 1928, pp. 93-94.

Account of old and modern American practice. Abstract of article in Iron Age, Jan. 26, 1928, previously annotated.

X-RAY ANALYSIS. Study of the Structure of Hardened Steel by X-Rays (Etude par les Rayons X de la structure de l'acer trempé), N. J. Seljakow, G. V. Kurdumoff and N. T. Goodtzow. *Revue de Métallurgie (Paris)*, vol. 25, no. 4, Apr. 1928, pp. 222-230, 7 figs.

Results of research along metallographic lines and discussion of results obtained. (Concluded.) Translated from Russian.

STEEL CASTINGS

INFORMATION SERVICE. Information. *Metallurgist (Supp. to Engineer, Lond.)*, June 29, 1928, pp. 81-82.

Attention is called to difficulties which have to be faced by technical industry in securing entirely reliable and up-to-date information on technical matters; describes organization for supplying information service of this kind set up in Philadelphia by group of steel castings manufacturers; they offer free information service to all users and prospective users of steel castings and free services of their experts in personal consultation, they also speak of cooperative research of practical nature on steel castings.

SLAG INCLUSIONS. Investigations of Slag Inclusions in Bessemer Steel Castings (Untersuchungen ueber Schlackeneinschluesse im Kleinbessemerstahlformguss unter Beruecksichtigung des Giessverfahrens), L. Treuheit. *Giesserei (Duesseldorf)*, vol. 15, no. 25, June 22, 1928, pp. 49-591, 32 figs.

Description of experimental method; influence of casting process on slag inclusions and piping; results show that steel cast through plug hole is less inclined to piping than when cast over lip by tipping.

STEEL FOUNDRY PRACTICE

Variables in Steel Foundry Practice, F. A. Melmoth. *Foundry Trade Jl. (Lond.)*, vol. 38, nos. 616 and 617, June 7 and 14, 1928, pp. 407-410 and 436-437, 2 figs.

Abstract of paper presented to Am. Foundrymen's Assn., previously annotated.

Steel Foundry Practice, P. Longmuir. *Iron and Steel Industry (Lond.)*, vol. 1, nos. 7 and 9, Apr. and June 1928, pp. 211-213 and 289-290.

Apr.: Actual working of acid open-hearth steel charge; whole of sequence of operations; melting period; formation of slag; working charge; sampling and making of necessary additions. June: Basic steel making discussed; evolution of process traced and functions of phosphorus and sulphur described; passing of wrought iron; effect of lime. (Continuation of serial.)

Unexpected Variations Dominate Steel Casting Practice, F. A. Melmoth. *Foundry*, vol. 56, nos. 12 and 14, June 15 and July 15, 1928, pp. 485-488 and 577-580, 7 figs.

June 15: Effects and influences of various elements in steel; normal ranges of elements as encountered in routine steel-foundry practice; silicon content; controlling manganese content; phosphorus limit given: July 15: Use of deoxidizers in steel and necessity of heat treatment.

Steel Foundry Practice, P. Longmuir. *Iron and Steel Industry (Lond.)*, vol. 1, nos. 4 and 6, Jan. and Mar. 1928, pp. 119-120 and 181-182, 2 figs.

Jan.: Practice of steel foundries making open-hearth steel castings from point of view of refractories employed; carbon as ideal neutral refractory material; chromite extremely useful. Mar.: Basic material in open-hearth refractories; open-hearth furnace in foundry; elasticity and adaptability in readily meeting demands of foundry floor become prime factors. (Continuation of serial.)

Make Steel in a Converted Iron Foundry, F. B. Pletcher. *Iron Trade Rev.*, vol. 83, no. 2, July 12, 1928, pp. 81-84, 6 figs.

Conversion of gray-iron foundry into plant of American Manganese Steel Co. for production largely of manganese and other alloy steel castings; steel melted in 1½-ton electric furnace; car-type mold-drying oven; 20-ton annealing oven; sand preparation and

handling equipment; cleaning and core room welding.

INGOT PRACTICE. Steel Ingots, F. equipment; two generators of oxyacetylene Beitter. *Metallurgist (Supp. to Engineer, Lond.),* June 29, 1928, pp. 83-85, 1 fig.

Author considers following points: question of temperature of molten steel and methods of measuring it; available means of regulating temperature of liquid steel; importance of avoiding turbulent flow of steel, whether in ordinary "top" casting or in bottom pouring; desirability or otherwise of ingots of circular cross-section and permissible ratio of length to diameter; rate of filling ingot mold, etc. Abstract translated from Stahl u. Eisen, May 3, 1928.

STEEL HEAT TREATMENT

TEMPERING. The Tempering of Steel. *Iron and Steel Industry (Lond.),* vol. 1, no. 8, pp. 261-262, 3 figs.

Process of tempering over which complete control achieved by scientific methods is necessary in order to secure uniformity of results, economy and efficiency; difficulties encountered in practice; Homo electric tempering furnace.

STEEL INGOTS

Influence of Molds and of Deoxidation on the Crystallization of Solidifying Ingots (Der Einfluss der Kokille und der Desoxydation auf die Kristallisation ruhig erstarrender Bloecke), F. Gadenheuer. *Stahl u. Eisen (Duesseldorf),* vol. 48, nos. 22 and 23, May 31 and June 2, 1928, pp. 713-718 and 762-766 and (discussion) 766-770, 19 figs.

Investigations on influence of mold-wall thickness on crystallization; effect of casting temperature and speed; influence of deoxydation on crystallization; segregation phenomena.

HETEROGENEITY. Heterogeneity of Steel Ingots. *Iron and Steel Industry (Lond.),* vol. 1, no. 9, June 1928, pp. 292-295 and discussion.

Critical summary of second report of Committee on Heterogeneity of Steel Ingots, presented at meeting of Iron and Steel Inst.; report deals in great detail with observations made on number of steel ingots varying from 15 cwts. to 119½ tons in weight; remarks made relative to oxygen.

HETEROGENEITY. Second Report on the Heterogeneity of Steel Ingots. *Foundry Trade Jl. (Lond.),* vol. 38, nos. 613, 614, and 615, May 17, 24, and 31, 1928, pp. 354-356, 369-372, and 383-389, 19 figs.

Account of alloy steel ingots produced from fully killed steel containing nickel, nickel and chromium, and nickel, chromium, and molybdenum; ingots studied indicate that high technical standard has been attained in production of such material. See also Iron and Coal Trades Rev. (Lond.), vol. 116, no. 3140, May 4, 1928, pp. 635-646, 26 figs., and discussion in no. 3140, May 11, pp. 714-715.

STEEL MANUFACTURE

CRUCIBLE PROCESS. The Use of High-Class Swedish Iron in the Manufacture of Crucible Steel. *Iron and Steel Industry (Lond.),* vol. 1, no. 8, May 1928, p. 249.

Ever since crucible process was started in Sheffield, Swedish bar iron has constituted main raw material; two main methods used in crucible process; charging crucibles; nature of slag.

DIRECT PROCESS. The Direct Production of Steel by the Flodin-Gustafsson Process (Verfahren zur direkten Stahlerzeugung nach Flodin-Gustafsson), S. Kalling. *Stahl u. Eisen (Duesseldorf),* vol. 48, no. 24, June 14, 1928, pp. 798-800, 1 fig.

Results of tests carried out in Hagfors, near Uddeholm, Sweden, making use of acid Bessemer and open-hearth processes; presents tabular data giving operating results, gas analyses, charcoal consumption, iron and slag analyses, and production costs. Abstract of report and discussion translated from Jernkontoret, 1927, pp. 35 and 51.

STEEL RESEARCH

Safe Loads for Steel Working at High Temperatures. *Iron Age,* vol. 121, no. 25, June 21, 1928, pp. 1749-1750, 4 figs.

U. S. Bureau of Standards publication gives data whereby superheated steam or chemical equipment may be designed; discussion of tests reported by H. J. French, H. C. Cross, and A. A. Peterson; five steels studied; at 800 degrees Fahr. boiler steel must be stressed considerably below 10,000 lb. per sq. in. if it is to remain in service indefinitely.

STRUCTURAL STEEL

SHIPBUILDING. Steel for Shipbuilding, W. J. Berry. *Engineering (Lond.),* vol. 125, no. 3256, June 8, 1928, pp. 720-721, and (discussion) 700-701.

Excepting high-tensile steels referred to, mild steel has held almost undisputed sway for last 40 years for shipbuilding purposes; standard tests adopted by Admiralty and Lloyd's for mild steel have remained unaltered for that period; in case of commercial structural steels, proportional range of elasticity is extremely variable; method stipulated for recording proportional limit of elasticity. Abstract of paper read before Instn. Civil Engrs. See also Engineer (Lond.), vol. 145, no. 3778, June 8, 1928, pp. 626-627.

TOOL STEEL

Tool Steels, Their Characteristics and Application, A. H. Kingsbury. *Can. Machy. (Toronto),* vol. 39, no. 13, June 28, 1928, pp. 114-118.

Comparison of methods employed in tool-steel industry of years ago with those of present day; essentials to quality; metallurgical laboratory; no inspection positive; normalcy of tool steels; classifications; constituent cementite.

ALLOYING ELEMENTS. Alloying Elements in Tool Steel. *Heat Treating and Forging,* vol. 14, no. 6, June 1928, pp. 639-641.

General effects of various elements entering into tool-steel alloys and ways in which they combine in metal; nickel; chromium; vanadium; tungsten; molybdenum; manganese; silicon.

WATER TANKS

STEEL—CORROSION. Excessive Corrosion of Galvanised Mild Steel Cisterns, H. F. Richards. *Iron and Steel Industry* (Lond.), vol. 1, no. 6, Mar. 1928, pp. 183-184, 4 figs.

Results of investigation on excessive corrosion taking place in galvanized mild steel cisterns; after 18 months' service as cold water reservoirs for hot water supply systems, cisterns became useless owing to perforation of bottoms by excessive corrosion; temperature factor in causing corrosion.

WELDS

HEAT TREATMENT. The Heat Treatment of Welds, G. R. Brophy. *Welding Engr.*, vol. 13, no. 6, June 1928, pp. 35-36.

Although heat treatment does improve results, necessity for it can usually be avoided by adopting correct welding procedure; heat treatment of weld holds great promise of improvement to physical properties; normalizing treatment, consisting of heating to from 950 to 1000 degrees Cent., for from two to three hours (in case of ½-in. plates) followed by rapid air cooling; role of manganese and carbon.

X-RAY ANALYSIS. Significance of X-Ray Studies of Welding Processes (Die Bedeutung der Roentgenuntersuchung in der Schweisstechnik), Kanter. *Autogene Metallbearbeitung (Halle, Saale)*, vol. 21, no. 2, Jan. 15, 1928, pp. 18-25, 14 figs.

Use of fluoroscope and diascope in study of structure of welds; description of special X-ray laboratory, using Seifert deep-roentgenotherapy equipment for metallographic studies; many examples of metallographic X-ray protographs of welds.

X-RAY ANALYSIS. New X-Ray Studies of Welding Technology (Neueste Versuche mit Roentgenstrahlen in der Schweisstechnik), Kanter. *Electrotechnik u. Maschinenbau (Vienna)*, vol. 46, no. 22, May 27, 1928, pp. 495-509, 18 figs.

Uses of X-ray in metallography, particularly in study of welds; description of modern apparatus used, details of X-ray study of welds of locomotive fire box; danger of working with X-rays; protective measures, lead shields, etc.

WIRE DRAWING DIES

The Development of the Diamond Drawing Die, E. Kay. *Wire*, vol. 3, no. 6, June 1928, pp. 191 and 209, 4 figs.

How American manufacturer has cut production costs one-third while improving quality; difficulties encountered by American manufacturer of diamond dies is lack of skilled domestic labor; consideration of operating defects due to settings.

WIRE, STEEL

PROPERTIES. Dependence of Physical Properties of Drawn Steel Wire on Natural Hardness and Stretching Process, W. Puengel. *Iron and Steel World*, vol. 2, no. 3, Mar. 1928, pp. 151-158 and 166, 7 figs.

Investigations to determine to what degree physical properties of drawn wire depend upon natural hardness and stretching process of drawing, and if determination of elongation, bending and twisting would give correct estimate of properties of drawn wire. Translated from Stahl u. Eisen.

COLD ROLLING. The Cold Rolling of Steel Wire, H. Goldschmidt. *Wire*, vol. 3, no. 2, Feb. 1928, pp. 43-46, 18 figs.

Rolling process applied to small gage wire shows advantages; choosing right calibre; rhombus with vertex angle of 100 deg.; principle of automatic lead proved very advantageous in experiments; transfer from rhombus profile to round cross-section of finished wire facilitated by intermediate profile; comparative breaking tests with drawn and rolled wire.

COLD ROLLING. The Cold Rolling of Steel Wire (Das Kaltwalzen von Eisendraehten), M. v. Schwartz and H. Goldschmidt. *Stahl u. Eisen*, vol. 48, no. 9, Mar. 1, 1928, pp. 265-268, 13 figs.

Account of tests whereby wire drawing was replaced by cold rolling; results demonstrate advantages of cold rolling; relative strength values of drawn and rolled wire.

DRAWING AND BLUEING. Effect of Drawing and Blueing on the Physical Properties of Wire, J. D. Brunton. *Wire*, vol. 3, no. 2, Feb. 1928, pp. 47-49 and 66-69, 3 figs.

Modifications in physical properties due to wire drawing depend chiefly on structure of steel before drawing and on amount of cold work put on it; tensile strength increased with corresponding reduction in ductility as measured by elongation; fatigue; power of endurance under alternating stresses; elasticity can be increased considerably in wire by blueing or heating to temperature below 400 deg. cent.

MANUFACTURE. The Production and Working of Steel Wire, H. J. Van Royen. *Iron and Steel World*, vol. 2, no. 2, Feb. 1928, pp. 93-94.

High degree of purity is required, and great uniformity in chemical composition to obviate disturbances in subsequent drawing and patenting operations; in working of high-grade steels, care should be taken to avoid decarburization; best wire is obtained when steel has sorbitic structure. From paper read at Symposium on Indus. Materials at Berlin.

WROUGHT IRON

METALLOGRAPHY. Metallography Simplified for Practical Use in Shop, E. Preuss, G. Berndt and M. v. Schwarz. *Iron Trade Rev.*, vol. 82, no. 26, June 28, 1928, pp. 1657-1658, 5 figs.

Differences in structure of wrought iron shown by differences in color of layers after etching; due to differences in color of structure, it is also possible to recognize changes in shape to which wrought iron was subjected during its working. (Continuation of serial.)

X-RAY RESEARCH

Recent Applications of X-Rays, V. E. Pullin. *Jl. of Sci. Instruments (Lond.)*, vol. 5, no. 2, Feb. 1928, pp. 41-47, 8 figs.

Scope of work of Radiological Research Laboratory at Woolwich; improvement of X-ray tubes, particularly with regard to their operation at extremely high potentials; improvement of necessary electrical apparatus; study of technique involved in high-power metal radiography; thickness of metal that is desirable cannot yet be dealt with; more penetrating rays urgently called for; work being done in realm of X-ray crystal analysis.

News of the Society

NATIONAL METAL EXPOSITION AND CONVENTION

THE Second Annual National Metal Week will be held at the Commercial Museum, Philadelphia, the week of October 8, 1928.

It is estimated that 25,000 or more scientists, executives and others directly interested in the metals industry will be in attendance. The three societies participating are the American Welding Society, the Institute of Metals and the American Society for Steel Treating. Splendid technical sessions have been arranged by all of the societies and this in itself will be sufficient to draw to Philadelphia "the largest gathering of metal experts ever assembled anywhere."

Forty-one papers, covering subjects of much interest to the industry and setting forth new ideas and adaptions, prepared by well-known men of the metal world, are scheduled for presentation at the various meetings of the American Society for Steel Treating. Worth-while comment and discussion will follow the presentation of these papers and the members of the society and their guests will find valuable information awaiting them at these sessions.

The large Commercial Museum, offering 80,000 square feet of available floor space will be occupied during the week of the National Metal Exposition, and exhibits representing a complete cycle in the metal working, fabricating and treating industries will be featured.

American Welding Society

An especially fine program is being arranged by the program committee of the American Welding Society for presentation at the various sessions to be held in the Bellevue Stratford in Philadelphia. The high caliber and current interest of the papers assures the members and guests of the Society a most instructive and valuable series of meetings.

The Welding and Cutting Exposition held under the auspices of the American Welding Society, and in co-operation with the National Metal Exposition, will afford those in attendance an opportunity to observe the latest and best equipment and development in this field. Approximately 10,000 square feet of exhibit space will be occupied by the exhibitors of the American Welding Society.

Institute of Metals

For the second year, the Institute of Metals will hold their fall meeting simultaneously with the American Society for Steel Treating. This has proven a very satisfactory arrangement, combining as it does the ferrous with the nonferrous industry. Arrangements have been made for one joint technical session with the American Society for Steel Treating, to be held in the Assembly Hall of the Commercial Museum on Wednesday afternoon, when a program of papers has been prepared which will be of interest to the mem-

bers of both societies. The headquarters of the Institute of Metals will be at the Benjamin Franklin Hotel.

CAMPBELL MEMORIAL LECTURE

Dr. W. H. Hatfield, Director of the Brown-Firth Research Laboratories, Sheffield, England, will present the Edward De Mille Campbell Memorial Lecture for the year 1928. Dr. Hatfield, whose reputation as a scientist and metallurgist is world-wide, will talk upon "The Application of Science to the Steel Industry." The Campbell Lecture will follow immediately after the Annual Meeting of the American Society for Steel Treating, which will also be held on Wednesday morning in the ballroom of the Benjamin Franklin Hotel.

ANNUAL BANQUET

On Thursday evening, October 11th, at 6:30 p.m. the annual banquet will be held at the Benjamin Franklin Hotel. It will be an "aviation affair" special emphasis being placed upon the valuable contributions of the metal industry to the progress of aviation. All seats are reserved; tables seat eight; tickets are $5.00 each. Reservations, with checks, will be accepted now.

DAILY NEWSPAPER

The Daily Metal Trade, published in Cleveland by the Penton Publishing Company, will again issue a special edition during the week of the National Metal Exposition, eight pages exclusively being devoted daily to the activities of National Metal Week. These issues will be mailed to the home address of the members of the American Society for Steel Treating, as well as circulated among the hotels and at the Exposition.

RAILROAD CERTIFICATES

Round trip tickets will be sold at fare and one-half to the members of the American Society for Steel Treating, on the identification certificate plan, certificates having already been sent to members. Please note that tickets purchased on the identification plan will not be accepted on extra fare trains. One certificate is good for your entire family.

HOTEL RESERVATIONS

Reservation blanks have already been sent to the members of the American Society for Steel Treating for use in making all reservations direct with managers of the various Philadelphia Hotels. The use of these blanks will assure proper and adequate accomodations. Hotel Benjamin Franklin will be the headquarters of the Institute of Metals and the American Society for Steel Treating, and the Bellevue Stratford for the American Welding Society. It is advisable to make early reservations.

The morning sessions of the various societies will be held in the hotels mentioned above, while the afternoon sessions will be held in meeting rooms of the Commercial Museum.

PLANT INSPECTION

An interesting schedule of inspection trips to plants in and around Philadelphia has been arranged for members and guests, beginning at 9:30 a.m.

each morning. Splendid opportunity is offered on these trips to absorb new ideas and helpful suggestions.

Technical Papers Program of the American Society for Steel Treating

An Investigation of the Physical Properties of Certain Chromium-Aluminum Steels—Frank B. Lounsberry and Walter R. Breeler, Atlas Steel Corporation, Dunkirk, N. Y.

Chromium-Copper Steels as Possible Non-Corrosive Ferrous Alloys—B. D. Saklatwalla and Albert W. Demmler, Vanadium Corporation of America, Bridgeville, Pa.

A New Development in Corrosion-Resisting Steel—Frank R. Palmer, Carpenter Steel Co., Reading, Pa.

Stainless Iron and Its Application to the Manufacture and Transportation of Nitric Acid—Walter M. Mitchell, Central Alloy Steel Corp., Massillon, Ohio.

Surface Hardening of Special Steels with Ammonia Gas Under Pressure—Raymond H. Hobrock, Engineering Experiment Station, Purdue University, Lafayette, Ind.

Methods of Approximating Certain Physical Characteristics of Nitrided Steel Cases—G. M. Eaton, Molybdenum Corp. of America, Pittsburgh.

Depth and Character of Case Induced by Mixtures of Ferro-Alloys with Carburizing Compounds—E. G. Mahin, University of Notre Dame, Notre Dame, Ind., and R. C. Spencer, Caterpillar Tractor Co., Moline, Ill.

Solubility of Carbon in Normal and Abnormal Steels—Oscar E. Harder, University of Minnesota, Minneapolis, Minn., and Willard S. Johnson, American Rolling Mill Co., Middletown, Ohio.

The Equation of the Carbon Time Curve in Basic Open-Hearth Refining and Prediction of Carbon Drop—Alexander L. Feild, Union Carbide and Carbon Research Laboratories, Inc., New York City.

A Melting Record of Three Acid Open-Hearth Heats—W. E. Griffiths, Union Carbide and Carbon Research Laboratories, Inc., Long Island City, and C. E. Meissner, Chrome Steel Co., Carteret, N. J.

Manufacture of Acid Open-Hearth Steel for Forging Ingots—H. P. Rassbach, Midvale Company, Nicetown, Philadelphia.

Deoxidation of Steel with Silicon—Dr. C. H. Herty, Jr., and G. R. Fitterer, United States Bureau of Mines, Pittsburgh.

Graphitization in the Presence of Nickel—H. A. Schwartz, National Malleable and Steel Castings Co., Cleveland.

Influence of Nickel on Combined Carbon in Gray Iron—J. R. Houston, The Harnischfeger Corp., Milwaukee, Wis.

Some Characteristics of Pearlite in Eutectoid Rail Steels—O. V. Greene, Reading Company, Reading, Pa.

Cutting Qualities of An Alloy Steel as Influenced by Its Heat Treatment—O. W. Boston, University of Michigan, Ann Arbor, Mich., and M. N. Landis, Landis and Landis, Chicago, Ill.

The Application of Science to the Steel Industry—By Dr. W. H. Hatfield, Sheffield, England.

Notes on Smoothing and Etching—H. B. Pulsifer, The Beryllium Corp. of America, Cleveland.

Further Observations on the Microstructure of Martensite—Francis F. Lucas, Bell Telephone Laboratories, New York City.

Treatment and Structure of Magnesium Alloys—John A. Gann, Dow Chemical Co., Midland, Mich.

Neumann Bands in Ferrite—C. H. Mathewson, Professor of Metallurgy, Yale University, New Haven, Conn.

A Study of the Constitution of High Manganese Steels—V. N. Krivobok, Carnegie Institute of Technology, Pittsburgh.

On Oxygen Dissolved in Steel and Its Influence on the Structure—M. A. Grossmann, Central Alloy Steel Corp., Canton, Ohio.
Surface Cooling of Steels in Quenching—H. J. French, G. S. Cook and T. E. Hamill, Bureau of Standards, Washington, D. C.
Tungsten Carbide, a New Tool Material—S. L. Hoyt, General Electric Co., Schenectady, N. Y.
Austenite Decomposition and Length Changes in Steel—Edgar C. Bain, U. S. Steel Corp., Kearney, N. J., and Willis S. N. Waring, Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.
On the Nature of Martensite Crystals—Dr. Kotaro Honda, Tohoku Imperial University, Sendai, Japan.
Torsional Modulus of Carbon Steel, Phosphor Bronze, Brass and Monel Metal—William P. Wood, University of Michigan, Ann Arbor, Mich.
Silicon-Manganese Steels with Chromium Additions for Engineering Applications—A. B. Kinzel, Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.
Evaluation of the Stability of Metals at Elevated Temperatures from Expansion and Short-Time Tensile Test Data—Albert E. White and Claude L. Clark, University of Michigan, Ann Arbor, Mich.
Cloudburst Process for Hardness Testing and Hardening—Edward G. Herbert, Edward G. Herbert, Ltd., Manchester, England.
Metallurgical Problems of Transmission Gearing—Ernest F. Davis, Warner Gear Company, Munice, Ind.
Decarburization of High Carbon Steel in Reducing Atmospheres—J. J. Curran and J. H. G. Williams, Henry Souther Engineering Co., Hartford, Conn.
Service Annealing of Sling and Crane Chains—W. J. Merten, Westinghouse Electric and Manufacturing Co., East Pittsburgh.
High Carbon, High Chromium Steels—J. P. Gill, Vanadium Alloys Steel Co., Latrobe, Pa.
Steel Failures in Aircraft—F. T. Sisco, Wright Field, Dayton, Ohio.
On the Equilibrium Diagram of the Iron-Molybdenum System—Takeshi Takei and Takejiro Murakami, Tohoku Imperial University, Sendai, Japan.
Effect of Furnace Atmospheres on Steels—R. G. Guthrie, Peoples Gas Light and Coke Co., Chicago.
Progress Made in the Use of Electric Furnaces for Heat Treating—A. N. Otis, General Electric Company, Schenectady, N. Y.
A New Method for Heat Treating High Speed Steel—Horace C. Knerr, Consulting Metallurgist, Philadelphia, Pa.
Heating High Speed Steel to 2400 Degrees Fahr. in Molten Lead—Wilbur C. Searle, Leland Gifford Company, Putnam, Conn.

MINUTES OF MEETING OF THE BOARD OF DIRECTORS

NATIONAL OFFICE, CLEVELAND, JULY 9 AND 10, 1928

Present

F. G. HUGHES	T. E. BARKER
ZAY JEFFRIES	L. D. HAWKRIDGE
J. M. WATSON	W. H. PHILLIPS
J. F. HARPER	W. H. EISENMAN

Absent

J. H. NEAD

Meeting convened at 10:00 A. M.

Upon motion properly made, seconded and carried, the minutes of the previous meeting of the Board were read and approved.

Treasurer Watson then presented the June financial statement and also an unaudited comparative profit and loss statement for the period from January 1 to June 30 for the years 1927 and 1928, and in addition a comparative balance sheet as of June 30 for 1927 and 1928.

Treasurer Watson also presented a series of blueprints portraying graphically the various expenses and income of the Society for a five months period of 1928 as compared with the budget for 1928. The various items on these reports were considered by the Board, and, upon motion by Dr. Jeffries, seconded by Mr. Barker, and unanimously carried, the reports of the treasurer were accepted and ordered filed.

Upon motion by Mr. Harper, seconded by Dr. Jeffries, and unanimously carried, the National Office was authorized to include professional cards in the advertising pages of the TRANSACTIONS.

The secretary then presented the following progress report on the Philadelphia exposition:

Philadelphia Exposition—Technical Program

The technical program is coming along very satisfactorily under the splendid chairmanship of Mr. Coleman who has worked conscientiously and hard, a complete well balanced program has been arranged. The ruling of the Board that all papers in order to be preprinted must be in the office 90 days in advance of the meeting has had a very salutary effect and 31 papers of those to be presented are now in the process of being preprinted. These will be available for distribution to the members on September 1st.

Arrangements are being made for outside activities. New innovations for this year will be as follows:

(1) All plant inspection is to be handled in the morning and not morning and afternoon as heretofore.

(2) There will be no smoker, Wednesday evening being left open and free.

(3) The exhibit will be open on Monday, Wednesday and Friday evenings as usual, and closed Tuesday and Thursday.

(4) The dance will be held on Tuesday night at the Benjamin Franklin Hotel.

(5) Morning technical sessions of all three convening societies will be held in the morning at the hotels; in the afternoons at exhibit hall.

(6) Special features for the exhibit are being arranged for special days. So far only the welding features have been settled upon. For instance, Monday will be devoted to demonstrations on welding nonferrous materials; Tuesday to welding of thin sheets; Wednesday to welding of pipe, all kinds and sizes; Thursday to welding of tanks, ⅛ inch and over; and Friday to fabrication of structural parts.

(7) It is proposed as far as the furnace section is concerned that those furnaces operating will have special days for the heat treatment of high speed, special days for the heat treatment of carbon tool steels, etc.

(8) It is proposed that this year there will be no regularly established golf tournament, but that arrangements be made with a number of clubs so

that members coming to the convention desiring to play golf will be able to make up their own parties and have access to conveniently located clubs.

The Banquet

With approval of President Hughes, we have arranged with a humorist from Chicago, Douglas Malloch, to be present at the banquet at the Benjamin Franklin on Thursday evening. President Hughes has already written and received tentative acceptances from Mr. Warner, assistant secretary of the Navy, in charge of aviation, and from W. B. Stout of the Stout Airplane Company. It is Mr. Hughes' plan that this banquet shall take on the nature of an aviation banquet because of the important part played by the steel industry in airplane construction.

Charles E. Carpenter has accepted an invitation to act as toastmaster.

Ladies' Entertainment

Mr. Briggs is again in charge of ladies' entertainment and is making arrangements with a capable Philadelphia hostess to carry out the details.

The secretary then presented the following progress report on the Los Angeles Exposition:

Western States Metal and Machinery Exposition Program

We have received word from W. H. Laury, chairman of the Program Committee, that his commitee is working on the available program and that all of the technical societies whose names are contained in our prospectus have appointed an individual to co-operate with the Program Committee.

Reservations

At the present time we have 68 distributors and firms who have made definite reservation for a total of $15,000.00, an average of better than $200.00 per exhibitor. Of this number 9 represent local Los Angeles firms, the remaining 59 are eastern firms that have made reservation for a space through their eastern office for the account of their western representatives. There are a large number of eastern firms yet to come in, and there will undoubtedly be also a large number of western firms that will participate.

Cleveland Exposition (1929)

The secretary then presented the following report on the Cleveland Exposition:

As previously indicated contract has already been executed and $500.00 deposit has been made for the Cleveland Annex and the Main Floor of Cleveland Public Auditorium for the 1929 exposition to be held the week of September 9th.

A. S. S. T. Handbook

The secretary then presented the following progress report on the publication of the A. S. S. T. HANDBOOK.

Practically all articles and sections for the handbook have been made up into pages, with the exception of four manuscripts and the nonferrous section.

The steel section to date totals 490 pages, with a possibility of adding two manuscripts of about six pages each. The nonferrous section is going to total

approximately 88 or 90 pages. The text matter for the book will, therefore, run about 600 pages.

With the exception of about 100 pages the material is okey, and is either in electros or in process of manufacturing electros.

A clear white, 40-pound base paper has been ordered, and delivery is expected July 15, which date it is also planned to go to press with the first forms.

The printer estimates six weeks for printing and binding, so September 1 should be the date the HANDBOOK is completed and ready for distribution.

Mr. Sisco is preparing the cross index.

The cover stock is to be duPont Fabricoid of a dark blue color with a medium grain embossing. An attractive cover design, which gives the title, edition, emblem and Society has been prepared by an artist. Dies are now being made from this copy for stamping the cover.

Correcting the Mailing List

The entire membership is now being circularized in order to correct the mailing list for the HANDBOOK. At the same time members have been requested to check certain items of products that they either manufacture or use so that we may have some statistics available for advertisers in TRANSACTIONS.

The number of HANDBOOKS to be printed has, after mature consideration, been increased from 7,500 to 8,000.

The secretary then presented the following report on Engineering Extension Work:

Engineering Extension Work

We have again made satisfactory arrangements with J. F. Keller to carry on extension work in the East. He has agreed and in fact there is in the office at the present time considerable of the material which we are to prepare in printed form for distribution to the members of his classes. We plan to publish this in book form.

Upon motion properly made, seconded and carried, it was determined that the Society should consider the development of an educational extension department as part of the general office activities.

Upon motion properly made, seconded and carried, the salary of assistant secretary Briggs was increased $600.00 per year.

A petition was presented in a letter from Walter Ogden, secretary of the Southern Tier Group, based upon the authority of their executive committee, requesting the advance of the Southern Tier Group from the group to a chapter rating. Upon motion by Mr. Barker, seconded by Mr. Eisenman, and unanimously carried, the petition was granted and Southern Tier was promoted.

The Board then gave consideration to some proposed changes in the Constitution, and a sub-committee was appointed to report at the following meeting (next day) on the proposed changes. The committee consisted of President Hughes and Messrs. Eisenman and Barker.

A report was read from the Constitution and By-Laws Committee on the proposed change of the name of the Society, this matter having been referred to the committee by the Board at their February meeting. The report follows:

"Dear Mr. Hughes:

In further reference to your letter of February 22 on the subject of the proposed change in the name of our Society, the matter has been referred by letter to each member of the Constitution and By-Laws Committee, and has had careful consideration. The consensus of opinion of the members of the committee is as follows:

Your committee realizes that it is not primarily either its duty or privilege, as a committee, to pass upon the advisability of a change in name. That is purely a question of policy for the consideration and action of the Board and of the members. The Board, however, has asked the members of the committee to express in their individual capacities as members of the Society their thoughts on the subject. This expression they are glad to give.

It is their unanimous opinion that there is no legal reason for a change in name. From the standpoint of policy, your committee believes that such a change would be inadvisable at the present time. The only reason advanced for the proposed change is that it might express more accurately the purposes of our Society. Whether any name could be put forth which would accomplish that result is doubtful. At least none has been suggested. The result of the adoption of many of the names proposed would be to limit rather than broaden the Society's scope which would thereby alienate a portion of its membership. Furthermore, a change in name would cause the Society to lose some of the advertising value and good will that the present name has brought to it.

On the whole, therefore, the members of your committee feel that the name American Society for Steel Treating, while possibly not ideal, is nevertheless well and favorably known and consequently adequate; that until conditions change materially the Society is quite as likely to enjoy prosperity and usefulness under that name as under any that has been or may be proposed.

Respectfully submitted,

Howard J. Stagg   T. E. Barker
F. H. Franklin   H. E. Handy
O. T. Muehlemeyer   S. M. Evans

Upon motion by Dr. Jeffries, seconded by Mr. Watson, and unanimously carried, the report was adopted.

Upon motion properly made, seconded, and unanimously carried, the meeting adjourned until 2:00 o'clock Tuesday afternoon.

The second session of the Board was called to order at 2:00 P. M. Tuesday with the same members in attendance.

The first order of business was the report of the sub-committee on Constitution and By-Laws appointed the previous day by President Hughes. The committee presented a report in the form of a communication to Mr. Havens, chairman of the National Constitution and By-Laws Committee, which report was as follows:

Mr. S. M. Havens
Wyman Gordon Company
Harvey, Illinois
Dear Mr. Havens:

By authority of the Board of Directors upon resolution at the meeting of the Board held in Cleveland, duly called for the purpose under Article XVIII, Section 1 (b)—It is proposed that the Constitution and By-Laws Committee incorporate in the Constitution the following changes of such specific points as indicated and make such necessary changes of other sections

of the Constitution and By-Laws as may be necessary in order that the entire Constitution may be in conformity.

(1) Amend the Constitution so that a member who permits his dues to become delinquent for one month shall be considered not in good standing and shall not thereafter receive the publications or other services of the Society.

This is to amend Article VII, Section 7, on the subject of non-payment of dues where at the present the Constitution provides that a member is not dropped from the rolls until after his dues have become delinquent for three months.

(2) The Board feels it desirable to omit the last sentence of Article VII, Section 7, which provides that a person whose dues shall remain unpaid for six consecutive months shall automatically cease to be a member of the Society.

The Board feels that this sentence may well be eliminated as according to present practice, a member whose dues are delinquent is automatically dropped and ceases to receive the services of the Society.

(3) The Board has decided upon recommendation of the auditors and others, as well as upon their own best judgment that the Constitution should be so amended as to permit the Board to designate a certain month upon which the dues for all members of the Society would become payable.

The Board has decided upon March but is not sure that it would be desirable to make the date a definite one but wishes to have the Constitution confer such authority upon them that they may be able to designate that all dues are payable on a fixed date.

(4) The Board would require power in addition to determining the date upon which dues to the Society shall be payable, the authority to prorate the dues of persons joining the Society on dates other than the annual anniversary for the payment of dues, according to whatever plan the Board may deem right and proper.

Very truly yours,

AMERICAN SOCIETY FOR STEEL TREATING

W. H. Eisenman *Secretary*

Upon motion by Mr. Watson, seconded by Dr. Jeffries, and unanimously carried, the report was accepted, and the secretary was instructed to notify Mr. Havens and his committee to follow the necessary procedure in order that the proposed changes might be ready for consideration at the annual meeting at Philadelphia in October.

The special Constitution and By-Laws Committee appointed by President Hughes the previous day presented the following amendments to the By-Laws of the Society:

Amendment to the By-Laws as follows:

Pursuant to Article VI, Section 1 of the Constitution which implies that the National Board of Directors has authority to deny any and all petitions for the granting of a charter, the following shall be the practice for granting of charters:

Group

Section 1. In cases where it shall appear to the National Office that there is a desire among a group of members interested in the work of the Society, in certain localities, where distance renders attendance at present chapter meetings impracticable, and where it may not appear at once that the permanence expected of a chapter is assured, power shall be delegated to the National Office and with the consent of the Board of Directors, to organize these members into a group.

Chapter

Section 2. Upon petition of the executive committee or membership of a group, the National Board of Directors shall investigate the feasibility of advancing such group from a group rating to a chapter rating. In general, the group shall have demonstrated the demand in the community for a permanent organization and shall satisfy the Board by its record of performance for 2½ years that such action is warranted.

Student Group

Section 3. Authority is hereby granted chapters subject to the approval of the Board of Directors for the establishment of student groups for the promotion of the objects of the Society in any institution of learning in their neighborhood. Such group shall be a part of the sponsoring chapter.

Upon motion by Mr. Harper, seconded by Mr. Watson, and carried, the proposed amendments to the By-Laws were adopted.

This new article is to be known as Article No. IV, and Article No. IV is changed to Article No. V; Article No. V is changed to Article No. VI; Article No. VI is changed to Article No. VII.

Upon recommendation of the new auditing firm of Ernst and Ernst and also based upon investigations, the Board approved of the new method of billing which will become effective immediately as follows:

First invoice to be mailed to the member one month in advance of due date.

Final invoice to be mailed on due date.

Member to be dropped 30 days after due date.

This means that the members who do not remain members of the Society will obtain one issue of the TRANSACTIONS after their dues have expired, and will place in effect a 30-day period of grace.

Treasurer Watson then presented a report from the Finance Committee relative to group insurance. Upon motion by Mr. Watson, seconded by Mr. Phillips, and unanimously carried, the report was accepted and the subject of group insurance tabled.

The Board of Directors then received and accepted Dr. Hatfield's lecture to be presented as the Campbell Memorial Lecture at the annual meeting to be held in Philadelphia. Upon motion properly made, seconded and carried, it was decided that the paper was to be preprinted and to be distributed free of charge in paper cover to those in attendance at the annual meeting; that it was to be then published serially in the TRANSACTIONS and then be available in bound form for sale at a price to be determined later.

Upon motion properly made, seconded, and unanimously carried, the meeting adjourned.

UNAUDITED FINANCIAL STATEMENT OF THE AMERICAN SOCIETY FOR STEEL TREATING

In connection with the statement published herewith, we wish to state that Messrs. Ernst & Ernst, Certified Public Accountants, have been employed and are auditing our records quarterly, and a certified Balance Sheet, together with a statement of Income and Expense, are to be submitted by them as of the close of business December 31, 1928, which will be published in TRANSACTIONS some time early in 1929.

UNAUDITED PROFIT AND LOSS STATEMENT
AMERICAN SOCIETY *for* STEEL TREATING

For the period from January 1 to June 30, 1928

INCOME			
Gross Dues		$ 36,217.95	
Transactions Advertising	$ 21,792.25		
Transactions Sales	534.71		
Transactions Subscriptions	1,380.55	23,707.51	
Reprints		755.07	
Bindery Account		821.00	
Book Account		2,271.92	
Pencil Account		41.12	
Pins and Buttons		21.00	
Miscellaneous Receipts		211.28	
Data Sheets	722.60		
Data Sheet Binders	270.50		
Data Sheet Books	20.00	1,013.10	
Discounts Received	306.59		
Interest	867.51		
Premium and Discount	525.00		
H. M. Howe Medal Fund	61.99	1,761.09	
Sustaining Exhibit Membership		4,200.00	
TOTAL INCOME			$ 71,021.04
EXPENSE			
Local Chapters		$ 16,236.90	
Semi-Annual Meeting		512.07	
Transactions		19,430.13	
Reprints		723.40	
Bindery		874.66	
Book Account		1,962.08	
Pencil Account		59.79	
Library		258.96	
Data Sheets		2,575.56	
Data Sheet Binders		6.65	
Discounts Allowed		254.33	
Bank Exchange		2.03	
General Expense		4,926.92	
Collection and Legal Expense		21.14	
Insurance		532.81	
Secretary's Office		7,972.34	
Treasurer's Office		2,980.01	
Directors' Expense		1,353.28	
National Committees		3,297.99	
TOTAL EXPENSE			$ 63,981.05
EXCESS INCOME OVER EXPENSE			$ 7,039.99

BALANCE SHEET As of June 30, 1928

ASSETS			
Commercial Account		$ 15,369.08	
Savings Accounts		10,875.06	
Accounts Receivable		5,640.62	
Accrued Interest		313.93	
Investments		127,000.00	
Office Furniture and Fixtures		3,778.28	
Inventory		4,535.70	
Prepaid Expense—			
Western States Metal Show		2,900.98	
1929 Convention		555.16	
1928 Convention		12,149.48	
TOTAL ASSETS			$183,118.29
LIABILITIES, RESERVES AND SURPLUS			
Accounts Payable		$ 2,027.07	
Advance Receipts, 1928 Convention		17,932.73	
Advance Receipts, Western Metal and Machinery Expo.		2,050.00	
Reserves		46,539.65	
Surplus			
January 1, 1928	$109,783.79		
Balance from Surplus Adjustment Acct.	2,254.94		
	107,528.85		
Excess Income over Expense for the period from January 1 to June 30, 1928	7,039.99	114,568.84	
TOTAL LIABILITIES, RESERVES AND SURPLUS.			$183,118.29

News of the Chapters

STANDING OF THE CHAPTERS

DURING the month of July there were 170 new and reinstated members, while 17 were lost through arrears, resignations and deaths, leaving a net gain for the month of 153 members. The total membership of the society on August 1, 1928, was 4858.

Membership standing of the society as of August 1, 1928, is as follows:

GROUP I		GROUP II		GROUP III	
1. Detroit	474	1. Los Angeles	159	1. New Haven	94
2. Chicago	439	2. Hartford	140	2. Worcester	73
3. Pittsburgh	356	3. Golden Gate	124	3. Washington	72
4. Philadelphia	317	4. Lehigh Valley	121	4. Tri-City	69
5. New York	314	5. Milwaukee	114	5. Rockford	60
6. Cleveland	299	6. St. Louis	107	6. Providence	56
7. Boston	253	7. Cincinnati	103	7. Rochester	54
		8. Indianapolis	95	8. Toronto	54
		9. Dayton	93	9. Southern Tier	53
		10. Syracuse	84	10. Columbus	49
		11. Canton-Mass.	83	11. Schenectady	44
		12. Buffalo	78	12. Springfield	39
		13. Montreal	69	13. Fort Wayne	28
		14. North-West	57	14. Notre Dame	23

GROUP I—All chapters in this group showed a gain with Detroit having the largest, 26; New York, 13; and Chicago and Cleveland, 10 each.

GROUP II—Los Angeles, with a margin of 19 and a net gain of 10 for the month, heads group 2. All of the chapters in this group with the exception of St. Louis, which advanced from seventh to sixth position, have the same standing as last month.

GROUP III—New Haven, with a gain of 2, now has a lead of 21 for first position. Worcester, with a gain of 5, advanced from fifth to second place, displacing Washington and Tri Cities. Toronto, with a gain of 6, passes Southern Tier and goes into a tie with Rochester for seventh place. The standing of the other chapters remains the same.

INDIANAPOLIS CHAPTER

The first annual June frolic of the Indianapolis Chapter was held Saturday, June 2, 1928. About ninety members and guests of the chapter motored to Idlewood Park, twenty miles northeast of Indianapolis, where the festivities of the frolic began at about 2:30 p. m.

The afternoon was devoted to sports, with the following prize contests: golf tournament, canoe races, foot races, and baseball. One or two of the canoeists were novices and preferred to swim after bucking a high wind upstream. Appetites were decidedly keen-edged when the chow-gong sounded at about 6 o'clock. A delicious fried chicken dinner was served, with no limits on consumption of chicken and all the fixings.

Following this glorious feast, the prizes for the events of the afternoon were awarded to the various winners. About ten men received valued merchandise certificates negotiable at Carter's on the Cirle.

The frolic was concluded with the annual chapter meeting, during which the following officers for the coming year were duly nominated, elected and installed:

Chairman, Edward J. P. Fisher, research metallurgist, Diamond Chain Mfg. Co., Indianapolis; vice chairman, Carl J. Winkler, general superintendent, Schwitzer-Cummings Co., Indianapolis; secretary, Nelson R. Gorsuch, industrial engineer, Citizens Gas Company, Indianapolis; treasurer, Richard S. Smith, assistant director of research department, E. C. Atkins Company, Indianapolis.

The chapter reports indicated a most successful year just ended and there is every indication of continued progress during the 1928-29 season.

N. R. Gorsuch.

LOS ANGELES CHAPTER

The song is ended but the melody lingers on—and what a memory. Well, to get down to business we all met at Ventura on the appointed day at the appointed hour and without any preliminaries, hied to the Wren's nest and started the works. (Saturday, July 21, 1928.) As usual our illustrious, industrious, etc., member, Ralph Hall, had everything in ship shape order for a real time. The program committee had a field meet planned which went off as follows:

First, the 100-yard dash with a beautiful cigar lighter as a prize and with eleven entries, it was some race. Winner, Keener Beale with Bill Farrar second, by two vest buttons, the rest all stringing out from inches to miles behind.

Secondly, the Shot Put and when this gang of steel heavers, etc., put a shot, it's put. Carl Fromme looked like a sure winner for a long time until Tom Hutton, Jr., came up to bat and with a mighty heave put the pill about 20 feet beyond the best put and carried off the bacon which was the aforementioned shot. Second prize, a Ludlum Steel Company stainless pocket knife went to Carl Fromme.

Next, the Potato Race which caused much amusement and resulted in E. M. Hienhold winning the hand bag donated by the Earl M. Jorgensen Company and the second prize, 5 gallons of motor oil, went to Jim Patterson who as he works for the Shell Oil Company needed oil badly. The booby prize went to Ben Dimend.

Fourth event was the Broad Jump and as first prize, the Ludlum Steel Company awarded a stainless steel carving set, which was carried off by

Mr. Frazer. The cigar lighter, which was the second prize, was won by Tom Hutton, Jr., with Bill Grau getting the booby prize.

Two Tug-of-War teams next lined up and with a team of high powered salesmen versus the operative men, it was some event. The rope was stretched to its limit and eventually the operative men copped the prize, cigars for all.

Then we ate, and if you can imagine the lucious dinners baked by Southern mammies plus real juicy barbecued steaks, you know how we ate. It was noticed that our chairman kept going back for more and he, by the way, was not the only one, everybody eating to the limit of his ability.

After the dinner, we all gave a rising vote of thanks to our hosts, Ralph Hall and the Shell employees, and then watched the final event of the afternoon, the Watermelon Eating contest, and as everybody had eaten to his utmost, this event was very slow, being won in thirteen seconds which is nine seconds behind the world's record. Prize, a beautiful silver hot water bottle, just the size to fit your hip pocket. This was won by E. M. Heinhold with Tom Hutton, Jr., getting second place and Mr. Renny the booby prize.

The gang then went to the Ventura Hotel and enjoyed the Badtime stories and played Tiddly-winks, Put and Take, etc., everybody having a great time.

Sunday morning, we went to the Ojai Golf Club and there competed in a tournament. The course is one of the sportiest on the coast and everybody acclaimed the tournament a success, and HOW. The cup for low gross was taken by Curly Wilkinson, who was just one point ahead of H. E. Hodward and Wade Hampton. The fur-lined heavy handled mug was carried off with great ado by our sandy haired member, Fred Arnold. There will be a play off for the net cup. Dates to be set later.

Items of Interest

BEGINNING July, 1928, a new monthly periodical: The "Bureau of Standards Journal of Research" will continue the publication of the two series of research papers heretofore issued—"Scientific Papers" and "Technologic Papers." Forty-four volumes (22 of each of the two superseded series) have been published, comprising some 942 research papers (572 on fundamental science and 370 on applied science).

The new journal will contain the bureau's research papers and critical reviews in the fields of science and technology. These will be comparable in interest and importance with the bureau papers already issued. The union of pure and applied science in one journal will, it is believed, tend to bridge the gap between the two fields, and by so much shorten the lag between discovery and its application. This makes it the more desirable that all engaged in scientific or technical work should have available for current use and permanent reference the new "Bureau of Standards Journal of Research." The paper page (size 5⅞ by 9⅛ inches) of the new journal will be about that of the Philosophical Magazine or the Annalen der Physik. Each volume (semiannual) will be indexed and a cumulative consolidated index will be included in the bureau's list of publications as heretofore.

One year's subscription to the Bureau of Standards Journal of Research in United States, Canada, Mexico or Cuba will be $2.75. For other foreign countries add 75 cents extra.

"A New Day in the Age of Iron," is the title of a booklet issued by the A. M. Byers Co., Pittsburgh. The process used by this company in the manufacture of wrought iron is explained.

A new bulletin suggesting possible applications for thermostats has been issued by the Robertshaw Thermostat Co., Youngwood, Pa.

The Brown Instrument Co., Philadelphia, has available for distribution catalog 93 covering resistance thermometers. This book fully describes the application and types of Brown resistance thermometers as applied to modern industry.

Bulletin 11, describing the latest development in Thwing radiation pyrometers, particularly describing the latest design of enclosed type radiation receiving tube may be obtained by addressing a request to the Thwing Instrument Co., 3339—41 Lancaster Ave., Philadelphia.

Alfred V. de Forest, research engineer for the American Chain Company, was recently honored by the American Society for Testing Materials, which organization awarded him the Dudley National Medal in recognition of his

achievement in perfecting the non-destructive test for materials. With the device Mr. de Forest has developed it is now practical for a person to sit in front of a machine and by means of a graph on which appears a hysteresis loop determine instantly whether or not the material passing in front of him has the slightest defect.

Magnetic analysis is a subject on which dozens of eminent research engineers have been working for years. Now the problem is solved through Mr. de Forest's sensitive electric galvanometer which will detect a flaw no bigger than a pin-head in the center of a large steel wheel, and all without cutting or marring the surface of the metal.

In operation, the galvanometer is comparable to the X-ray which penetrates the tissues of the human body without harming them. With the newly developed instrument a plate or piece of steel five or six inches thick may be explored almost as though it were made of glass.

No doubt this invention will have a far-reaching effect on the quality of all materials used in industrial machinery. As an instance, just one of the important uses to which it may be applied is the inspection of steam turbine wheels. Such wheels with their buckets frequently operate at speeds upwards to 3,600 revolutions per minute, and should a flaw deep in the center of the steels of which they are made cause a section to fail, the resulting destruction would be terrific. Countless other, and equally important, applications await its production.

Mr. de Forest graduated from Massachusetts Institute of Technology in naval architecture in 1912. He was with the New London Ship and Engine Company for one year, after which he became instructor in civil engineering at Princeton. He later studied metallography at Columbia, then spent two years in the research department of the Remington Arms Union Metallic Cartridge Company. Since 1918 he has been chief research engineer for the American Chain Company, his activities extending to the products of all the American Chain associate companies, such as the American Cable Company, Page Steel & Wire Company, Manley Equipment Company, Reading Steel Casting Company, Dominion Chain Company, and others.

The American Gas Furnace Co., Elizabeth, N. J., has issued bulletin 12-A covering carburizing machines and furnaces. Both the rotating and vertical carburizing equipments are described. It is stated that both types may be used for hydrogenizing and for nitrogenizing.

The Chrobaltic Tool Co., Detroit, announces that the Louis C. Ertzen Co., 280 Broadway, New York, has been appointed as its agent in the metropolitan territory.

The Poldi Steel Corp., of America, New York, has for distribution a leaflet devoted to the various specialized tool steels manufactured by the Poldi Steel Works, Prague, Czechoslovakia.

The steel sales division of the Timken Roller Bearing Co., Canton, Ohio, has issued an illustrated booklet showing various operations in the manufacture of Timken Steel.

(*Continued on Page* 36 *Adv. Sec.*)

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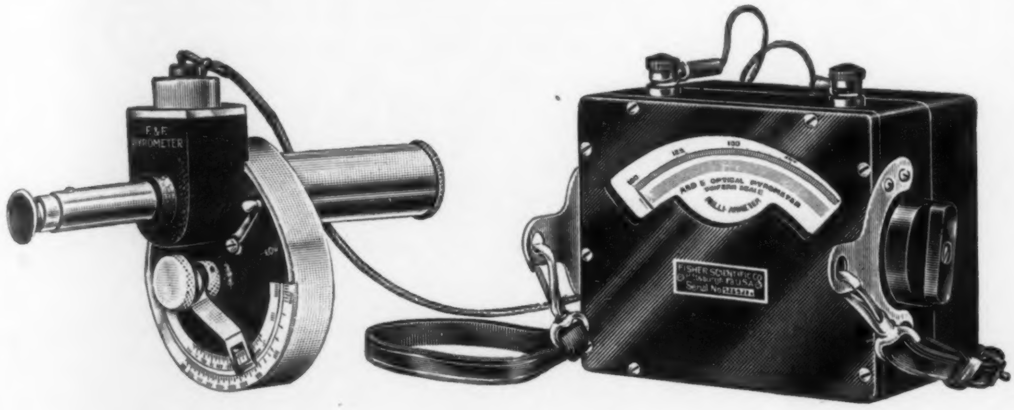

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C. M. Rutledge, who has been connected with the Columbia Tool Steel Co. for the past nine years as sales representative and assistant district manager at Chicago, is now affiliated with the Vanadium Alloys Steel Co. at Chicago.

"Used Experience, The Key to Future Nickel Steel Applications," is the title of a booklet issued by the International Nickel Co., New York. This booklet is devoted to the use of nickel steel in various types of equipment and shows the methods of disseminating knowledge to all classes of users.

The bulletin dealing with various uses of its special flux in cupola practice, in desulphurizing by adding it to cast iron in the ladle and in brass melting has been issued by the Mathieson Alkali Works, Inc., 250 Park Ave., New York.

"Castings that Must Never Fail," is the title of a circular issued by the Lebanon Steel Foundry, Lebanon, Pa. Electric Steel Castings used in rock drill equipment are described.

Applications for junior metallurgist must be on file with the Civil Service Commission at Washington, D. C., not later than September 25, 1928. The examination is to fill vacancies occurring in the Federal classified service throughout the United States. The entrance salary is $2,000 a year. Higher salaried positions are filled through promotion.

The duties will consist of general metallurgical work connected with the fabrication of manufactured articles, either ferrous or nonferrous; general metallurgical work, including process control, physical testing of metallurgical materials or ores, microphotography and research work on a large variety of metallurgical problems.

Competitors will be rated on practical questions on general metallurgy, chemistry, and elementary physics, and on a thesis handed to the examiner on the day of the examination.

Applications will be accepted from senior students in accredited educational institutions subject to their furnishing during the existence of the eligible register resulting from the examination proof of actual graduation.

Applications for associate or assistant physicist must be on file with the Civil Service Commission at Washington, D. C., not later than September 26, 1928.

The examinations are to fill vacancies in the Bureau of Standards and the Bureau of Mines of the Department of Commerce, and under the National Advisory Committee for Aeronautics.

The entrance salaries are $3,200 a year for the associate grade and $2,600 a year for the assistant grade. Higher-salaried positions are filled through promotion.

The Link-Belt Co., Chicago, Indianapolis and Philadelphia, has issued general catalog 500 containing 1088 pages covering engineering data and list prices for the complete chain, sprocket, power transmission, elevating and conveying divisions of the company's business.

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